THE COMPOSITION OF TECHNICAL PAPERS

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OF
TECHNICAL PAPERS

BY

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PREFACE

The teaching of English composition to engineering students has taken two directions, one liberal, the other professional. The first of these, following the present trend of engineering education away from narrow over-specialization, aims to give the engineering student substantially the same course which is given his brother in the liberal arts college, with the difference, sometimes, that the specimens of exposition analyzed in class and the theme subjects assigned are meant to be of especial interest to engineers. The second has the more immediate aim of preparing the engineering student to write successfully such papers as his vocation will demand of him. The first regards the embryo engineer primarily as a future member of society; the second regards him primarily as a future engineer. The division between the liberal and the professional aims is not, in the case of instruction in English composition, sharp, since any engineering student who receives one type of instruction will receive with it much of the value contained in the other type. And the two types are not by any means antagonistic. Every engineering student should certainly have a general course in English composition; and most engineering students are given such a course, usually in their freshman year. But experience has shown that they can also take with great profit special instruction in the composition of technical papers. After they leave college, they will be members of a social organization, and the liberalizing value of the general course will be of undoubted service to them. But the bulk of whatever writing they will do will almost certainly be of a professional kind, and a special course in the composition of technical papers will, therefore, also be of undoubted service. Any professional course so special in its nature that its value to the student rapidly evaporates with the progress of engineering science may be called narrow and may properly be ruled from the curriculum of the engineering college. A course in the composition of technical papers cannot, however, be narrow and comparatively valueless, inasmuch as the elements of which it is composed remain constant from year to year with their value to the student unimpaired by any advance in engineering knowledge. A course in the composition of technical papers, therefore, although it may be described as professional, is not open to the danger of deterioration in value which threatens many other professional courses.

The aims and methods of a course in general composition for engineering students have been set forth by the present writer in an article on *The English Department and the Professional Schools* in the *Bulletin* of the Society for the Promotion of Engineering Education for October, 1916. The working material for such a course will be found in Professor Frank Aydelotte's *English and Engineering* (McGraw-Hill Book Company, 1917). *The Composition of Technical Papers* is designed to provide material for a course of the second type. The book is the result of a teaching experience of several years at the University of Wisconsin, and embodies the methods employed there in a one-semester, three-hour course elective for juniors and seniors in the College of Engineering. All of these students had taken the regular freshman English course in their first year; a very few had also had other university courses in English composition. The book has been written, however, with regard to its possible use in a first course in college English. It has one aim and only one,—to teach engineering students to write better technical papers.

Under the conditions prevailing at Wisconsin the following course elements seemed to produce the best results:

1. Two weekly class meetings for informal talks on technical writing, analyses and study of specimens from various sources, drill in paragraphs and sentences, and other class exercises.

2. A weekly five-hundred word theme of the type under consideration in class.

3. A regular weekly conference of at least fifteen minutes with each student.

4. A semester paper of from two to three thousand words on a subject of especial interest to the student.

At the class meetings students were expected to join freely in the discussions, and were encouraged to bring to class articles from technical magazines which seemed worthy of especial comment. The conferences were substantially private lessons based on the weekly themes. Students usually regarded them as one of the most serviceable elements in the course. The semester paper was the *pièce de résistance* of the theme work; it was begun early in the semester and was supposed to occupy the student's attention throughout the course. Many of these papers, it might be added, were subsequently published, either in technical magazines or as separate pamphlets, a circumstance which greatly stimulated the interest and activity of the students.

My obligations to those who have assisted me directly or indirectly in the preparation of the volume are heavy. I owe much, undoubtedly, to the authors of the numerous text-books which I have used in my courses in composition. My most conscious obligation in this direction is, however, to the almost indispensable Woolley's *Handbook of Composition*, which I have used in my classes for years, and upon which I have drawn more heavily perhaps than I realize for my chapter on the sentence.

A number of busy engineers and editors of technical magazines have given me suggestions for the development of the Wisconsin course in technical writing, and I wish to take this occasion to acknowledge the courtesy of the following gentlemen: Professor Charles F. Scott, Mr. Percy H. Thomas, Mr. Ralph D. Mershon, Mr. S. E. Doane, Mr. Ralph Beman, Mr. E. J. Edwards, Mr. Frank J. Sprague, Mr. G. A. Wardlaw, Mr. Walter Jackson, Mr. W. D. Weaver, Mr. A. L. Rohrer, Mr. Charles B. Going, Mr. C. W. Baker, Mr. Gano Dunn, Mr. B. K. Boyce, and Mr. P. W. Kinney. To Mr. M. C. Rorty of the American Telephone and Telegraph Company I am indebted for material for class use and for many helpful suggestions, and to my brother, Mr. H. W. Watt of the Westchester Lighting Company, for a careful criticism of the manuscript of the entire book and for other assistance.

From the following members of the Engineering College faculty at Wisconsin I received assistance of various kinds: Professors J. W. Watson, C. I. Corp, M. C. Beebe, L. F. Van Hagan, and Mr. F. E. Volk, Librarian of the Engineering Library.

Messrs. H. A. Burd, S. B. Harkness, and H. L. Ridenour of my own department at Wisconsin read parts of my manuscript and assisted me with many suggestions. To Professor F. A. Manchester of the English Department at Wisconsin I owe an especial debt; he read the manuscript of the first part of the book with his usual patience and care, and corrected my judgment and style at several points. Professor W. R. Raymond of the Department of English of the Iowa State College of Agriculture and Mechanic Arts provided me with a very useful list of technical articles.

Specific acknowledgments for permission to reprint articles or parts of articles have been made at the appropriate places within the book. No attempt has been made always to indicate the source of short paragraphs and sentences used in the first part for illustrations; in many cases I could not now give the source.

Finally, I owe a lasting debt to my students in the Wisconsin course in technical writing, whose interest in the work was a continued source of inspiration to me, and from whose class papers I have drawn freely for illustrative material.

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CHAPTER I

INTRODUCTION

The Value to the Practicing Engineer of a Training in English Composition

"An engineer who is inarticulate," said a well-known New York engineer in speaking of the value to members of his profession of a thorough knowledge of English, "is quite as useless as one who is professionally incompetent." This is a terse and vigorous expression of a truth which all experienced engineers recognize, that the man who has not the power to give his ideas clearly to others, the man whose thoughts are locked in his brain simply because he has not the ability to communicate them, suffers under a handicap which no amount of professional knowledge can possibly overcome. The engineer is not a hermit in his profession, shut off from all intercourse with others; his work is indissolubly bound up with that of other men, and he finds himself constantly obliged to communicate with them. The men employed by an electric-light company, from the president down to the humblest clerk, are individuals each busied with his own particular task, to be sure, but each contributing toward a common end—the success of the company. And because of this common aim they are in constant communication with one another, by word of mouth, by letter, by written report. It can, then, be readily perceived that the failure on the part of any individual employee to make himself clearly understood by other employees will often affect very seriously the efficiency of the whole machine. An incomplete, indefinite, or ambiguous report from a foreman, for example, may temporarily delay the progress of an important piece of work. The more clearly and effectively the communication of ideas is carried on, the more efficiently will the common work of all be accomplished. And the employee who is best able to express himself clearly and exactly is the one who will stand the best chance, other things being equal, of advancement. The young engineer who writes the clearest, most accurate report, the foreman who can explain exactly and in a few words just what he wants done, are the men whom the superintendent is bound to notice. There is more than one instance on record of promotions which have come solely as the result of the ability to write a good report.

But it is not only in his daily routine that the engineer is called upon to express himself clearly; it often happens that he has an even harder task to face than that of making himself clear to his fellow-workmen and to his employers. The engineer often finds himself obliged to make clear to outsiders, to laymen, certain facts or ideas which it is desirable that they understand. A city engineer, for instance, may be asked to explain to the city council the nature and operation of a sewage disposal plant which they have been considering. It is evident that he must make an explanation which will not only be understood by a municipal engineer but which will be so free from technical details and language that the physicians, lawyers, and business men on the council will have no difficulty in following it. Similarly a mining engineer may find himself face to face with the problem of explaining to a group of capitalists the nature of some project in which they are interested; and in this case his explanation must not only be absolutely clear, but it must often be vigorous and persuasive. If he does not know best how to select, arrange, and present his material, he is very likely to confuse and tire his listeners without enlightening them.

All of these demands upon his skill in speaking and writing will come to every engineer; to the ambitious and successful engineer will almost certainly come in addition the desire to put his ideas into "guid black prent" or the invitation to address some technical or lay association. However valuable the ideas which he may wish to present on these occasions may be, his printed article or his address is not likely to be to his credit if he is incoherent or weak. The editors of technical journals do not care to give up the valuable inches in their magazines to men who do not know how to say what they wish to say; and societies soon cease to invite to their platforms men who ramble, stammer, and confuse them with illogical and unentertaining presentations. On the other hand, the engineer who is skillful and clear and easy in speech and written expression never knows the depressing feeling of inability which comes to the untrained man who tries to express himself, and the more depressing sense of failure which comes to such a man at the realization that his readers can not understand him or his audience follow him.

There is one further reason for the engineer's considering as important the ability to express himself correctly; it is, that incorrect expression marks him at once as crude and uncultivated. To be able to communicate with one's colleagues and to be able to explain to interested outsiders the nature of one's work are professional accomplishments. But the engineer is more than a professional being; he is a social being as well. And, it might be said in passing, few persons realize how closely their professional interests are bound up with their social accomplishments. The engineer who uses bad grammar and loose, incoherent expressions in his social communications, spoken or written, with men of other professions, stamps himself at once as unpolished, and often shuts himself out from a circle of acquaintanceships which would broaden his interests and freshen his ideals. He may acquire money in spite of this handicap, but he is not likely to attain a high position in his profession or to win the respect of his associates.

The inability of the engineer, then, to communicate his ideas clearly, concisely, and accurately will not only handicap him in many ways but may even affect detrimentally the work of others with whom he is associated. His ability, on the other hand, to speak and write with coherence and force is a professional and social accomplishment the value of which no thinking engineer will deny.

The Types of Writing with which the Engineer is Concerned

The principles governing composition were worked out through a long process of experimentation in which obviously good and obviously bad pieces of writing were analyzed to determine what made them good in the one case and bad in the other. If an explanation seemed clear and vigorous, the rhetorician asked, "What has the writer done to give it these desirable qualities?" If it was, on the other hand, obscure and difficult to follow, the question asked was, "What has the writer failed to do or what wrong thing has he done so to confuse his reader?" By this and similar processes of analysis it was determined that there are certain principles and tricks of the trade of writing, an allegiance to which produces in composition such desirable qualities as unity of effect, clearness, ease, and vigor, and the violation of which tends to produce the opposite qualities. Hence come books of rhetoric which aim to teach men to write by setting forth and illustrating the principles thus discovered. Many of these principles are little more than the sorting out and labeling of what to a man of native intelligence seems obviously the common-sense thing to do, and the "born writer" or the man who has by extensive reading of the best in literature acquired a sense for what is correct in writing may feel little need for the cold principles. Unfortunately, however, few men are born writers, and not many have the desire or opportunity to acquire correct form by the uncertain process of extensive reading; to the average man, therefore, the so-called "rhetorical principles" provide an extremely valuable short-cut to correct writing. It should, of course, be evident that a mere study of the pure theory of writing, without analysis of good examples and without practice in composition, is of no more value than the reading of a treatise on swimming without accompanying observation and practice. But properly assimilated and applied the principles of good writing may be made very serviceable.

Any "course" in composition consists of the study of the principles of clear thinking and correct and effective writing, and, in addition, the supervised application of these principles in written compositions, or "themes," of varying lengths and varieties. "The following practices," says the teacher at the beginning of such a course, "have resulted in the production of good writing; if you apply them with a reasonable amount of skill, and if you do not violate what modern, national, and reputable writers have declared to be good usage in other respects, what you write should possess the fundamental qualities which will make it clear and pleasing to your reader." Many of these practices are so fundamental that they apply to the writing of the engineer as much as to that of the literary man. The engineer is concerned, however, with certain of these principles more than with others, with those that arise from the particular kinds of writing in which he is professionally interested.

Writing is ordinarily divided into four types: narration, description, exposition, and argumentation. This division is, of course, a purely artificial one, made for purposes of analysis and study; writers do not usually say as they pick up their pens, "Now I am going to write narration," or, "This composition will be a specimen of argumentation." The distinction between the forms is not always easy to make. Poe's *Gold-Bug* is obviously narrative, and a book on alternating currents is just as obviously expository; but *The Story of a Piece of Coal* and *My Trip to a Copper-Mine* are narrative in form while expository in substance. It is safest, on the whole, to determine the type not from the title and form but from the content and evident aim of the writer. If his attempt is to entertain the reader in a succession of events told for their own sake or because of their artistic entanglement, he is writing *narration.* If he is attempting to reproduce in the mind of the reader an image, feeling, or impression which he has received, he is writing *description. Exposition,* or explanation, deals with facts or ideas; the writer's purpose here is usually didactic—he aims to enlighten his reader. *Argumentation* is exposition charged with persuasion; the facts become proofs, and the writer attempts not only to enlighten the reader but also to convert him to his own way of thinking. Examined in the light of these brief definitions *My Trip to a Copper-Mine* is seen to be really exposition, since the writer's aim is clearly didactic. Similarly the "story" part of *The Story of a Piece of Coal* appears merely as the seasoning of the explanation—the sugar coating on the pill.

The professional writing of an engineer, judged from the content and from the aim of the writer, is all exposition or argumentation. This statement does not mean that bits of pure description or even of narration may not occasionally enter in; it does mean, however, that the attitude of the engineer in all his professional writing is that of an expositor or of a propagandist, of an individual possessed of certain information which it is his aim to pass on to his reader, or of a man making converts to his way of thinking. Where he is not arguing, the engineer is always enlightening or explaining. An examination of the kinds of writing with which the engineer is concerned reveals at once the expository basis of it all. The explanation of a process, for example, whether it be the explanation of a method of analysis or of a process of manufacture, is, like *The Story of a Piece of Coal*, narrative only in form. The arrangement of material is almost certain to be chronological, but the content is that, not of a narration, but of an exposition, and the aim of the writer is clearly to enlighten his reader, not merely to entertain him. Similarly the engineer may describe a new hydro-electric plant, but here he is not by any means attempting merely to create in the mind of the reader a picture of the plant; this may be a necessary subordinate part of his object, but his chief concern is in making clear certain details of construction and operation; he is, in other words, explaining. In this case and in the case of the explanation of a process the engineer's attitude of mind toward his reader is quite different from that of the writer of artistic description and of narration. Other kinds of engineering writing, definitions and abstract expositions, such as explanations, for example, of physical laws and the setting forth of theories, belong clearly within the field of exposition. Reports and letters are special forms of writing which contain certainly more expository than other elements. Arguments, as has been said, are explanations charged with persuasion. A study of argumentation has its basis in an understanding of the principles of expository writing; to this is added a study of the principles of persuasion and conviction.

Since the professional writing of the engineer, therefore, is practically all expository or explanatory, the engineer is concerned in his study of the laws of good writing mainly with the principles of exposition writing. He must know the fundamental difficulties which beset the writer of expositions, and how to avoid them; he must learn the laws of good general organization and of the minor compositional units, the paragraph and the sentence; and he must, finally, devote especial attention to the forms of expository writing with which he is professionally concerned, explanations of processes, technical descriptions, reports, and letters. All these parts of his study will be taken up here in regular order. First, of course, comes a consideration of some of the fundamental and initial difficulties which he will encounter, and suggestions for avoiding and correcting them.

CHAPTER II

FUNDAMENTAL PROBLEMS AND SUGGESTIONS

Getting the Reader's Point of View

Writing is a process of transferring to others by means of visible symbols ideas which exist originally in our own minds. It is one means of *expression*, of transmission of thought. Speech, which is another means of expression, is at best an imperfect medium for conveying ideas; and writing, deficient in those auxiliary devices of intonation, facial expression, and gesticulation which speech possesses, is even more imperfect. The ideas of the average man are very likely to be badly jumbled; his brain has a curiously perverse trick of skipping from one detail of a subject to another in a most irregular manner, and only the most strenuous efforts at mental concentration will bring order out of chaos. But even when the writer has finally succeeded in getting his mind to thinking clearly and connectedly, he has made only the initial step; there still remains the *writing*, the translation of the ideas into the written symbols which are to stand for them. And here a thousand pitfalls yawn for him. He may carelessly separate ideas which belong together; he may over-emphasize an unimportant idea by giving it too important a form or too emphatic a position, or he may under-emphasize a really important thought by subordinating it in construction or in position; he may select a word which does not at all convey the idea which he intended it to carry; he may even by an incorrect construction obscure the meaning of his idea entirely or in some cases give a thought exactly the opposite of that which he had in mind. A knowledge of the errors in expression which result in the reader's misunderstanding, and then constant vigilance in guarding against these errors is the price of clear, effective writing.

The most fundamental cause of failure in writing is the inability of the writer to realize the absolute dependence of the reader for his understanding of the ideas to be conveyed upon the written expression of those ideas. Most writers are too self-conscious; they forget that they are writing not for themselves but for other persons. They forget that if the reader knew as much about the subject as they do, they need not write at all. It may happen, to be sure, that their reader is already familiar with certain of the ideas with which they are dealing. Essentially, however, the relation of writer and reader is this: the writer has in his mind certain conceptions, whether they concern facts, concrete mental images, or abstract ideas, which the reader is not in possession of; it is his task to transmit these conceptions as accurately as possible. The writer is manifestly better situated than is the reader, for after he has completed his paper, he possesses not only the written expression of the ideas which he gives the reader—his manuscript—but he has also the original ideas as they exist in his mind; whereas the reader must reach the mind of the writer solely through the imperfect medium of the author's manuscript. Herein lies the writer's difficulty; he reads his paper over before giving it to the reader and unconsciously corrects from the fullness of his own knowledge those gaps and inaccuracies in expression which cause the reader to scratch his head and ask, "Now what does he mean?" In other words, the writer is handicapped by his very knowledge of his subject; he cannot understand why what is perfectly clear to him in his paper should not also be perfectly clear to his reader.

It should, accordingly, be the aim of the writer to approach as nearly as possible the point of view of his reader. In fact, the more closely the author can identify himself with the reader, the more clearly will he write. Very careful writers usually submit their manuscripts to friends or to paid readers before sending them to the publishers, because they realize that expressions which seem intelligible to them may not seem so at all to others. This method of testing out the clearness of what has been written is not, of course, always practicable; too often the only reader is the one for whom the paper is intended. But within certain limits the writer can be his own preliminary reader. This he can accomplish by training himself to take a mercilessly critical attitude toward his writing. He can not make any expression absolutely fool-proof, but he can with care so write that there is very little danger of his being misunderstood. Such a principle of workmanship often means rewriting and painstaking correction; but this much care is due the reader. If Huxley, a master of prose style, could afford to rewrite one of his lectures seven times, writers less skilled can hardly afford to impose upon their readers hasty, unrevised compositions of any sort. One very practical means which the writer may adopt of disconnecting himself from his original thoughts and of thereby approaching the point of view of his reader is that of putting his composition aside for a period of time until what he *intended* to say has become less fresh in his mind; then he will be better able to judge of the clearness of what he *actually has said* and to correct his sins of omission and of commission. This process is, of course, not always possible; wherever it is done, however, it never fails to result in a clearer piece of writing.

There is one specific part of this problem of identifying oneself with the reader which needs especial emphasis. The writer must be very careful to use language which the reader will understand. Any technical writer, whether he be engineer, lawyer, or physician, is likely, often without realizing it, to use a professional jargon which only the initiated can understand. The engineer should remember that he is not always writing for engineers. When he is composing a report for his superior, or when he is addressing an engineering society, he will naturally make use of the technical language of his profession; when, however, he is writing a general report for a committee of capitalists, or when he is addressing a city council, he must use a language which they will understand. Many professional men take a very natural pride in appearing learned in their profession; the most successful professional men, however, recognize the fact that simplicity of language and phrasing is more to be desired than a glossing of technical expressions. One of the best known hydraulic engineers in America, who recognizes this principle fully, recently wrote in the Letter of Transmittal accompanying a report addressed to an exploiting committee:

"I have, as far as possible, endeavored to avoid technicalities and to make my meaning so plain that my statements can be understood and my reasoning followed by any business man, even though unfamiliar with water power. For this reason I have included in the appendix various information of technical matters and further discussions of important matters which, if discussed in the body of the report, would have been objectionable."[1]

This same engineer explained the somewhat intricate operations of a hydro-electric plant and certain problems connected with it so clearly that probably not one of his audience of business men, teachers, and lawyers failed to understand him. He did it simply by avoiding technical terms and technical details as far as possible and by using a great many concrete examples and comparisons drawn from the common experience of all of his listeners. Huxley could, before an audience of his scientific associates, make free use of scientific words and details which would drive the average university graduate to desperation; he could, on the other hand, make the most difficult and abstract scientific matters perfectly clear to an audience of London laboring men simply by keeping constantly in mind the limits of their scientific attainments and by meeting them on the ground of common experience.

The extent to which language and manner of presentation should be adapted to the reader must, of course, be predetermined in every case. A report addressed to a veteran engineer will obviously be different from the same report addressed to a business man. For that uncertain individual, the general reader, it is safest to avoid technical expressions as far as possible; the reader can forgive the writer who is occasionally too simple in his explanation but he can not forgive the writer who is unintelligible.

[1] DANIEL W. MEAD: *Report on the Water Power of the Rock River*, Jan. 1, 1904.

To avoid technical language and to write simply is not in the least to lower one's professional dignity. In fact, to be able to make a technical matter clear to a man who has no knowledge of one's profession requires skill of a very high order. The writer who can do this successfully has no difficulty in being technical enough when occasion demands it.

Mechanical Devices for Assisting the Reader

Psychologists assert that eighty-five per cent. of a man's information comes through his eyes, and there is an old saying that "you can get more knowledge into a man's head through his eyes with a teaspoon than you can get through his ears with a scoop-shovel." The mind of every reader yearns for a graphic representation of the ideas which he is reading, and it is a part of the duty of the writer of technical articles to satisfy this desire. Accordingly, any use of diagrams, drawings and illustrations, curves and statistical tables is not only perfectly legitimate but often absolutely necessary to a complete and accurate understanding of a difficult exposition. A single sketch, carefully executed, will often give the reader more information than pages of written explanation. On the other hand, it is quite possible for a careless, inaccurate drawing to add to the confusion which comes from an incoherent explanation. Attention to a few simple principles in the use of these auxiliary devices will, therefore, save the reader much annoyance.

All diagrams and sketches should be neatly and carefully done; a slovenly, careless drawing detracts from the appearance of the manuscript and disgusts the reader even where it does not mislead him. The drawing should be set off distinctly from the text; if a liberal white margin does not surround it, it fails to stand out and is, therefore, difficult to examine. Parts of the drawing referred to in the text should be carefully lettered; all such letters should be conspicuously and unmistakably placed so that the reader does not have to search for them and so that he can readily connect each letter with the part to which it refers. Where there are several drawings in a manuscript, it is often advisable to give a title to each one in addition to its number. The reader is often helped, moreover, by finding beneath each drawing in which there are several parts referred to by letters, a table giving the letters alphabetically and the names of parts to which the letters refer; this should be done in addition to giving text references. Economy in the use of diagrams and drawings is desirable; for example, in a description of a slide-rule it is better to show in a single sketch the rule and the inserted slide projecting than to use two separate sketches, one for each part.

Many of the suggestions given for sketches apply also to curves and tables. Accuracy and care are very essential. Visual devices to assist the reader may also be used here; for example, in the case of long statistical tables occasional vertical and horizontal lines drawn between rows of figures will break up the mass and assist the eye to read the numbers. Two or more tables or curves used in comparisons should, where possible, be put side by side so that the comparison which the reader is expected to make can be carried on readily.

In addition to helping his reader by using sketches, curves, and tables, the writer of technical articles may make use of certain mechanical devices in his manuscript. The listing and numbering in the introduction of the parts of a subject to be taken up and the corresponding naming and numbering of each division as it is begun in the body is a very useful device for assisting the reader to follow the plan of an article. In articles of some length, moreover, the newspaper practice of inserting occasional sub-titles is often very helpful. When these are put in the margins, they become to the article what a thumb-index is to a dictionary; they guide the reader in his perusal of the article and enable the busy man who is looking for only a part of the paper to find that part immediately. All such devices as these, where they aim really to assist the busy reader and are not mere useless flourishes, are perfectly legitimate and dignified.

CHAPTER III

PRINCIPLES WHICH GOVERN THE PLANNING AND WRITING OF THE WHOLE COMPOSITION

Selecting the Subject

The problem of knowing what to write about does not ordinarily trouble the engineer, for usually his subject is either assigned to him or suggests itself. In the case of reports the writer always has a more or less definite problem set for him. Where he is more ambitious than the average engineer, who writes nothing but reports and letters, and feels called upon to publish in the technical press some of his ideas or the results of some of his investigations or observations, he usually waits until a subject which is worth while suggests itself. The man who wants to print *something*, it does not matter what, merely for the sake of advertising himself is the only writer who has to cast about for a subject. The engineer, on the other hand, who feels seriously the duty of assisting his brother engineers in the solution of the problems which daily confront them does not bombard the editors of technical magazines with commonplace descriptions of perfectly commonplace engineering constructions or with vain repetitions of ideas as ancient as Euclid; he waits until he has some idea which he conscientiously believes to be fresh and likely to be interesting or until he has met a new problem or worked out a new solution of an old one. Such subjects, the only ones really worth accepting, do not have to be sought for; they come to the writer with the conviction that they are certain to interest his readers.

Thinking the Subject Over

Once the subject has been thus assigned or suggested, the writer may begin work at it immediately by turning it over and over in his head as a lawyer would revolve in his mind one of his cases and as a teacher would think over the problems connected with the teaching of a difficult lesson. The writer can not, by taking thought in this way, add anything to his actual knowledge of the subject; he can, however, by this process clarify what ideas he may have and decide many questions of arrangement and presentation of material. No writer should attempt to do any writing whatever until he has given his subject this chance to grow into some definite substance and form. In composition it is the brain which is the creative instrument, not the fingers. While he is thinking his subject over, he should ask himself repeatedly, "Now what is the best division of this material?" "Which of these points should come first?" "Where can I get an illustration of this idea?" "Will my reader understand this?" and similar questions which aim to stimulate his thinking and to assist him in getting the point of view of his reader.

Gathering Information

While this process of revolving the subject in his mind is going on, he will, of course, be adding, if necessary, to his stock of information on the subject. Such information may come from a reading of technical books or journals, from actual inspections and investigations, from interviews with authorities, or sometimes, in the case of an exposition setting forth an opinion, from a simple gathering together of the experiences of the writer and of others to prove a theory or belief. He should be in no hurry to get to the actual writing. He should think over his material for as long a time as possible; then, when he actually does begin the transference of his ideas to paper, he will be full of his subject and will write with more spontaneity and flow and ease than he would otherwise. When he finally begins the process of actual composition, he comes face to face with the problems of *writing*, or presenting his ideas.

The Cardinal Principles of Exposition: Unity, Coherence, and Proportion

Analyses of all but mere one-paragraph compositions show them to be made up of words which are grouped into sentences, sentences which are grouped into paragraphs, and paragraphs which are grouped together to form the whole composition. Now the writer who conscientiously desires to give his readers the very best expression of his ideas must attend constantly to *all* of these divisions. If his paragraphs are loosely constructed, the fact that the general organization of the paper is good will not excuse him; if his sentences are unintelligible, his readers will not forgive him because his paragraph divisions seem correctly made. Theoretically, then, it would be best for the student who combines study of theory with practice in writing if he could learn *at once* all the principles relating to the whole composition, the paragraph, and the sentence, since in any composition which he writes he may violate any of them; practically, however, the principles which govern each division must be taken up separately. We shall, accordingly, take up first the most essential principles of effective exposition in so far as they affect the whole composition.

The first principle with which the writer is concerned is that of *Unity*. Unity means *oneness* of composition; to secure it the writer must stick rigidly to his subject and avoid all temptation to digress. Although this may seem to be a simple practice to follow, it is by no means easy at all times to define rigidly the limits of the subject with which one is dealing and then to avoid breaking over the line which has been set. There are constant temptations to drift off into details which have only the remotest connection with the subject, and before the writer realizes that he has been wandering, he is far afield. Even clear-headed lecturers sometimes digress in this fashion until their listeners nudge one another and ask, "Now what does he think he is talking about anyway?"

To secure unity it is necessary for the writer first, to form a very definite idea of the scope of his subject, and, second, to guard himself constantly lest he go outside the limits which he has set. In some forms of engineering writing these precautions are not very difficult to observe. When one is writing a descriptive-explanation of a machine, for example, there is not much danger of his writing about anything but the machine, although even here he may set out to write a mere description and find himself talking about the advantages of the type of machine under consideration over other types. Again, an explanation of a process is easy to unify if one is careful to stick to a simple narrative account of the different stages in the process. The principle of unity is most likely to be violated when the subject does not suggest at once its own limitations, in which it is necessary, in other words, for the writer to set his own boundaries. Such subjects as explanations of abstract theories, comparisons of different methods of manufacture, and many forms of reports are much more difficult to unify than are descriptive-expositions of machines or explanations of processes. In all cases where the limits are not more or less definitely set by the nature of the subject, it is necessary for the writer to determine just how much should be included for the particular purposes of the paper and just exactly what belongs to the subject; he must, in other words, draw a circle very definitely about his subject. This limitation predetermined, there remains the still harder task of guarding constantly against stepping beyond it.

An example or two will make this principle clearer. If a writer is explaining the various methods of wood preservation by impregnation of the wood-fiber with creosote and other preservatives, he must not allow a chance reference to the necessity of conserving lumber to sidetrack him upon a discussion of conservation problems and a tirade against timber thieves; these are interesting matters, but they are not a part of his immediate subject. Long-winded and ponderous introductions are the worst offenders against unity. A description of a recent improvement in an electric cooker need not begin with a history of the cook-stove, and it is not necessary to introduce an explanation of the process of lumbering with a two-paragraph glorification of the forest primeval. The writer should know definitely what the limits of his subject are and then should stay within those limits from beginning to end.

One of the most effective ways of forcing an observance of unity is for the writer to state definitely at the beginning of his paper the limits of his subject. The value of such a device is twofold: first, it gives the reader at once a definite idea of what the subject and its limits are, so that he knows from the beginning what the paper is about; second, if the writer keeps his own statement of limitation clearly in mind, he is far less likely to wander from his subject. Of course, in forming his statement of limitations, he will not find it necessary always to use the same stereotyped phrases. He need not always say, "It is my purpose, etc.," or "This paper will take up, etc." The information given must be modified to suit the subject, and the baldness of the device as a piece of compositional machinery can be concealed in a hundred different ways.

Even more important than the principle of Unity in the whole composition is the principle of *Coherence*, the *sticking-together* of the various parts of the composition. Good unity comes mainly from a careful selection of the details which go into the paper; good coherence comes principally from a careful arrangement of those details. A disassembled machine lying on the floor in a heap of parts may certainly be said to possess unity, potentially at least, since all the necessary parts and no more are present; coherence it does not have until a skilled mechanic puts all the parts together in their proper relationship one to another. Similarly, a writer may have determined accurately enough just what should go into his paper, but if he then throws his ideas together with no regard for good order, the result will be chaos. Careful planning and organization is as essential to a paper as it is to a machine. And yet many a writer will plunge in at one end of a composition with only the vaguest idea of the course which he will take.

Good coherence in a paper can not be secured without, first, a careful division into parts, and, second, a logical arrangement of those divisions. Just what the best division and arrangement of parts of any composition is will be determined largely, of course, by the nature of the subject. Some subjects are, obviously, more easy to handle than others. An explanation of a process of manufacture, for example, will naturally follow a chronological arrangement, the different parts of the composition corresponding to the various stages in the process. An expository description of a machine will usually be built up by giving first a general idea of the principle of operation and of the essential structure of the machine, which will serve as a basis for the reader's understanding of the details, and then a description of the details grouped in some regular order which must be determined by the nature of the subject. Compositions dealing with subjects less concrete are, of course, much harder to handle. Each of such subjects presents its own problem. The writer must in all such cases work through his material very carefully, determine into just what divisions the material had best be separated and just what the clearest and in general most effective arrangement of these divisions will be. It will often be found that the divisions of the subject may be arranged in the order of importance, either the most important first, or, if the writer wishes a strong climax, sometimes last. Often, too, in the case of certain subjects, the general explanation must precede the details; this arrangement is sometimes obviously necessary since it would be impossible for the reader to understand the specific details without having first read the general explanation. Quite frequently the order of divisions is determined by the circumstance that any other arrangement would be illogical and unintelligible. In general, too, the arrangement will often be determined largely by the audience addressed and by the specific aim of the writer. Examples of various arrangements of material are given in the specimen outlines on pages 34–43.

Whatever type of exposition the writer may be concerned with, and however simple the problem of arrangement may be, it is almost always best for him to make a written outline before beginning to write. Many writers like to claim that they "never make an outline." Now what these writers really mean is that they never make a *written* outline; it is almost inconceivable that any writer would plunge into a composition without having some notion, however ill-defined, of what he is going to say and of how he is going to say it. In the case of very short compositions and of those with a very simple arrangement of parts, it is possible and permissible for the writer to make and carry the outline in his mind, as an impromptu speaker does when suddenly called upon for an after-dinner speech. With longer and more complex pieces of work, however, not to make a pretty definite written plan of the composition is to be extremely negligent. A contractor might build a chicken-coop for himself without any blueprint to guide him; but if he were to attempt to build a three-story dwelling-house for somebody else without a very exact set of plans and specifications, he would probably be called a fool and released on the spot. Now a piece of writing is just as much a problem of organization, of putting parts together properly, as is a building, and if the writer would build his composition well, it is as necessary that he should have a guide to go by as that the contractor should have his blueprints. To write without such a guide results invariably in a waste of energy and time and almost as certainly in an incoherently arranged piece of exposition.

Concerning the value of the written outline the *Suggestions to Authors*, published by the American Institute of Electrical Engineers, says:

"The task of preparing a technical paper is greatly lightened by constructing and following a well-considered plan, and no writer should undertake to prepare a paper without first preparing a definite plan upon which his paper is to be constructed. The simplest way to do this is to make an outline or skeleton of the paper similar to a table of contents, using a separate heading for each main division of the subject and appropriate sub-heads under each heading to cover subdivisions of the subject. This affords a ready means of arranging the contents of the paper in logical order, and the actual writing of the paper consists merely in filling in one or more paragraphs under each head.

"Another method preferred by some authors is to write upon cards hints and suggestions in regard to the paper, and when ready to prepare the manuscript, sort out the cards in their proper sequence. Then expand the suggestion on each card into one or more paragraphs which fully express the ideas which the writer intends to convey."

Aside from the written plan as a guide, the mere exercise of working over the outline clarifies one's ideas and gives one a much firmer grasp of his material. A well-known hydraulic engineer once remarked that he found the mere practice of outlining his knowledge of any subject excellent, since it gave him a clearer conception of the relation and comparative values of divisions under the subject. It is well, then, if the writer wishes to have a coherent arrangement of his subject and to give himself a clear idea of the relation of parts for him to make a written plan before he begins the actual writing, to draw a chart, so to speak, of the proposed journey.

The mere form which an outline should have is not so essential as that it should be logically sound and therefore an adequate guide to the writer. For after all, an outline, useful as it is, is only a working plan and is of no more value to the writer after his paper is in final form than is the plan of a house to the persons living in the finished structure. It usually happens, especially in the case of long papers, that the fuller the outline is in ground covered and in statement, the better it is, and for this reason an outline which is a complete synopsis of the exposition is usually the best. But the true test of the value of an outline lies, after all, in its logical soundness and in its consequent adequacy as a reliable guide, and for this reason an outline which is merely a list of titles of the main divisions with a similar list of the sub-divisions may be quite as satisfactory for a working plan, provided that the writer has organized his subject thoroughly, as a fuller one. The weakness of such an abbreviated outline is that it does not pin the writer down quite so rigidly to his plan; its meshes are wider, and there is more chance of his slipping out. But if it is correctly and logically constructed, and if the writer has his material well in hand, it will be quite sufficient for his purposes, especially if his paper is a short composition with no great complexity.

But whether the full synoptical or the short topical form be used, the outline, in order to be a reliable guide, must in either case set forth the true relationship of parts in the composition. What is meant by logical soundness in an outline may be illustrated in a simple hypothetical case. Let it be assumed that, omitting a possible introduction and conclusion, an examination of the subject-matter of a proposed paper shows it to fall into three main divisions, I, II, and III, that a further examination shows each division to be made up of three sub-divisions, A, B, and C, and that finally each sub-division is found to have three parts, 1, 2, and 3. The outline, represented by the mere symbols would then be:

I. . . . .
    A. . . . .
        1. . . . .
        2. . . . .
        3. . . . .
    B. . . . .
        1. . . . .
        2. . . . .
        3. . . . .
    C. . . . .
        1. . . . .
        2. . . . .
        3. . . . .
II. . . . .
    A. . . . .
        1. . . . .
        2. . . . .
        3. . . . .
    B. . . . .
        1. . . . .
        2. . . . .

3. . . . .
C. . . . .
1. . . . .
2. . . . .
3. . . . .
III. . . . .
A. . . . .
1. . . . .
2. . . . .
3. . . . .
B. . . . .
1. . . . .
2. . . . .
3. . . . .
C. . . . .
1. . . . .
2. . . . .
3. . . . .

An actual outline would not, of course, present such uniformity as does this hypothetical one. Now if this outline has been properly constructed, an examination of it will show all divisions which are given equal rank to be actually coördinate, although not necessarily of equal importance. For example, I, II, and III must be coördinate; and under each of these divisions, A, B, and C must be coördinate. Furthermore, if the outline has been properly constructed, an examination will show that each sub-division is a *true* sub-division of the governing division under which it stands. For example, 1, 2, and 3 under I B must all be *factors*, so to speak, of I B; it will not do for one of them to belong under, let us say, II B. If the outline has been solidly constructed, in other words, the following equations will prove true:

$$A + B + C = I,$$
$$1 + 2 + 3 = I\,A,$$
$$1 + 2 + 3 = I\,B,$$ and so on for each division.

The sum of the coördinate sub-divisions will in each case be equivalent to their governing division.

The following outline of a descriptive-exposition is manifestly defective:

MISSISSIPPI RIVER SURVEY BOAT

I. The party.
  A. Why it is necessary to have a boat.
  B. Organization of the party.

II. Outside appearance of the boat.
  A. General appearance.
  B. Method of mooring the boat.

III. Interior of the boat.
  A. Beds.
  B. Drafting table.
  C. Dining table and benches.
  D. Ice box.
  E. Kitchen which included the stove, cupboards, etc.

It will be observed here, first, that the major divisions, I, II, and III, are not coördinate, I being clearly introductory to the other two. The sub-divisions are also illogical. I A does not belong under I; II A is practically equivalent to II, and II B has nothing whatever to do with II; and under III there is no reason for the "stove, cupboards, etc.," being lumped together while the ice box, beds, and other articles of furniture are dignified by separate division. The reader might assume from the outline, moreover, that the crew cooked, ate, slept, and worked in the kitchen since no other room is mentioned; even the kitchen, according to the outline, is of no more importance as a whole than any one of the articles of furniture mentioned under III A, B, C, and D.

An attempt has been made in the following revision to correct these errors:

A MISSISSIPPI RIVER SURVEY BOAT

Introduction:

I. Definition of a survey or "quarter" boat.
II. The necessity for such a boat.
III. The "crew" of the boat.

Body:

I. The exterior of a typical survey boat.
  A. General appearance and dimensions.
  B. The raft part.
  C. The house part.
II. The interior of the boat.
  A. General appearance and division into rooms.
  B. The living-room.
    1. General appearance and dimensions.
    2. Furniture.
  C. The kitchen.
    1. General appearance and dimensions.
    2. Furniture.

Before the series of outlines of various types which follows is examined, one final word needs to be said about outlining. It should always be remembered that an outline should not be used slavishly; if it is found after a part of the paper has been written that the outline can be improved, this improvement should always be made even to the extent of throwing the outline away and beginning all over. It is very seldom that a house is completed exactly in accordance with the original plans, and it very often happens that a composition is not finished according to the first outline. On the other hand, if an outline has been thoughtfully and carefully made, the writer should be slow to change it unless he is certain that his reorganization will result in better coherence.

The following outlines will serve as illustrations of the principles of outlining.

Outline 1

THE ELECTRIC FURNACE

Introduction:
- I. Definition.
- II. General description.
- III. Principle of operation.
- IV. Uses.

Body: Detailed description of the essential parts of the furnace.
- I. The resistor, or conducting material with high resistance.
- II. The envelope of refractory material.
- III. The electrodes.
- IV. The metal clamps to hold the electrodes in place and make connections with the cables of the circuit.
- V. The accessories, consisting of:
  - A. Cables.
  - B. Measuring instruments.
  - C. Regulating devices.

Outline 2

THE TWO-CYCLE GAS ENGINE

Introduction:
- I. The principle of operation of internal-combustion engines.
- II. Definition of the two-cycle gas engine.

Body:
I. Description.
  A. Cylinder.
  B. Crank case.
  C. Piston.
  D. Connecting rod.
  E. Crankshaft.
  F. Flywheel.
II. Operation.
  A. Admission of gas.
  B. Compression in crank case.
  C. Admission to cylinder.
  D. Compression.
  E. Explosion and working stroke.
  F. Exhaust.

Conclusion:
I. Uses of the engine.
II. Advantages over other types.
III. Disadvantages.

Outline 3

RATING A WATER-CURRENT METER

Introduction:
I. Definition of the meter.
II. General outline of the method of rating.

Body:
I. Method of making the rating.
  A. Preliminary steps.
    1. Laying out the base line.
    2. Setting the transits.
    3. Hanging the meter.
    4. Arranging the block and tackle.
  B. Final rating.
    1. Moving the boat.
    2. Timing the velocity.

3. Counting the revolutions.

II. The use of the data obtained.

Outline 4

THE LAYING OF UNDERGROUND CONCRETE CONDUITS

Introduction:

I. Underground conduits in general; definition and uses.

II. The all-concrete conduits.

Body:

I. Parts used in laying concrete conduits.
   A. Chairs.
   B. Wooden molds.
   C. Weights.
   D. Slabs.

II. Method of laying the ducts.
   A. Excavating.
   B. Laying the concrete foundation.
   C. Placing the chairs, molds, and weights.
   D. Pouring the cement.
   E. Drawing the molds.
   F. Laying the slabs.
      1. Pointing up.
      2. Cleaning the ducts.
   G. Adding the successive layers.
   H. Topping off and filling.

Conclusion:

I. Advantages of the all-concrete ducts.

II. Disadvantages of the all-concrete ducts.

Outline 5

HOW PHOTOGRAPHS ARE MADE

Introduction:

I. Definition of photography.

II. Brief outline of the essential steps in the making of photographs.
III. Description of the camera.
    A. Essential form and details.
    B. Classification into principal types.
IV. Announcement that this explanation will be concerned only with the taking of photographs with a plate camera having a fixed focus.

Body:
I. Loading the camera.
    A. Definition of this stage of the process.
    B. The plate-holder.
    C. The plate.
    D. Loading the holder.
    E. Putting the holder into the camera.
II. Making the exposure.
    A. Definition of this stage of the process.
    B. Timing the exposure according to:
        1. Intensity of light.
        2. Nature of the object photographed.
    C. Removing the plate-holder slide.
    D. Releasing the shutter.
    E. Replacing the plate-holder slide.
III. Making the negative.
    A. Definition of this stage of the process.
    B. Classification of methods used into:
        1. Hand method.
        2. Tank method.
    C. Explanation of the two processes.
        1. Hand method.
            a. General outline of the process.
            b. Preparing the baths.
            c. Developing the plate.
            d. Rinsing the plate.
            e. Fixing the plate.

f. Washing the negative.
g. Drying the negative.
2. Tank method.
a. Essential differences between tank and hand methods.
b. Description of the tank.
c. Preparing the baths.
d. Developing the plate.
e. Rinsing the plate.
f. Fixing the plate.
g. Washing the negatives.
h. Drying the negatives.

IV. Making the print.
A. Definition of this stage of the process.
B. Limitation of the subject to printing by artificial light.
C. Preparing the baths.
D. Making the exposure.
E. Developing the print.
F. Rinsing the print.
G. Fixing the print.
H. Washing the print.
I. Drying the print.

Conclusion:
General hints and suggestions for the successful taking of photographs.

Outline 6

The Sanderson X-ray Machine

Introduction:
I. The increasing field of the X-ray tube in:
A. Radiography.
B. Fluoroscopy.
C. Therapy.
II. Conditions which stimulated the development of the Sanderson machine.

Body:

I. Electrical principles of the machine with diagram of connections.

II. Enumeration and description of parts as fulfilling the electrical functions above mentioned.

   A. Rotary converter: synchronous motor.
   B. Transformer.
   C. Rectifier.
   D. Spark points.
   E. Control switchboard.
   F. Tube.

III. Assembling of the apparatus.

   A. Transformer cabinet.
   B. Switchboard.

IV. Operating merits of the machine.

   A. Electrical.
   B. Mechanical.
   C. Assemblage.

Conclusion:

The complete success of the Sanderson machine in solving the different problems of X-ray work.

Outline 7

Proposed Reorganization of an Electrical Testing Laboratory

Introduction:

I. A testing room is absolutely necessary:

   A. To make certain that apparatus will do the work for which it was designed.
   B. To ascertain whether apparatus has been built as designed.
   C. To check the mechanical strength and the machine work.
   D. For purposes of advertisement.

II. The requirements of an electrical testing room are:

A. It must be in close proximity to the shipping room.
B. It must be easy of access to all departments of the shop.
C. It must be sufficiently equipped with:
 1. Ammeters and voltmeters.
 2. Testing boards.
 3. Rheostats.
 4. Motors.
 5. Testing benches.
D. It must be under efficient management.
E. Its managers must keep good permanent records.

Body:

I. The objections to the present testing room at the M— manufacturing plant are:
 A. It is poorly located.
 B. There is no arrangement for future expansion.
 C. The branch testing rooms are too widely distributed.
 D. The equipment is antiquated.
 E. The management is inefficient.
 F. The records are badly kept.

II. The following changes should be made:
 A. The testing room should be put into a new building offering better opportunity for expansion.
 B. The room should be located:
  1. Nearer to the shipping room.
  2. Nearer to the source of electric power.
  3. Nearer to the two elevators.
 C. The room should be reëquipped.
 D. The present apparatus should be rearranged.
 E. The management should be reorganized so that:
  1. A foreman has charge of each bench.
  2. Unskilled labor is used for minor testing.
 F. The records should be more systematically kept.

Conclusion:

If the proposed changes are carried out, the result will be:

A. A certain saving of money.
B. Provision for future expansion.

The following three outlines are the tables of contents of three technical papers published by the Bureau of Mines.[1] It will be observed that such tables are in effect brief outlines.

Outline 8

THE RATE OF BURNING OF FUSE AS INFLUENCED BY TEMPERATURE AND PRESSURE

By W. O. Snelling and Willard C. Cope

Introduction:
  Nature and composition of fuse.
  Descriptive terms.
  Composition of fuse powder.
Rate of burning.
  Normal rate of burning.
  Influence of pressure.
  Influence of temperature.
  Influence of moisture.
  Influence of mechanical injury.
Practical conclusions.

Outline 9

METHODS OF ANALYZING COAL AND COKE

By F. M. Stanton and A. C. Fieldner

Introduction:
Preliminary treatment of samples.
Methods of analysis.
  Moisture.
  Ash.
  Volatile matter.
  Sulphur.
  Carbon and hydrogen.

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Nitrogen.
Phosphorus.
Determination of the calorific value of coal.
Standardization of the calorimeter.
Determination of the true specific gravity of coal and coke substance.
Determination of the apparent specific gravity.

Outline 10

THE FACTOR OF SAFETY IN MINE ELECTRICAL INSTALLATIONS

By H. H. Clark

Introduction:
Classification of accidents due to electricity.
Electric shocks.
Danger from ground-return circuits.
Dangers from trolley wires or bare conductors.
Danger from accidental charging of equipment.
Shocks from locomotives and cars.
Relative danger from different voltages.
Fires caused by electricity.
Explosions caused by electricity.
Ignition of explosives.
Accidents due to electrical shot firing.
Ignition of gas.
Ignition of coal dust.
Conditions surrounding electrical installations in mines.
Physical conditions.
Temporary character of installations.
The prevention of accidents caused by electricity.
Elimination of contributory causes.
Confinement of the current.
Additional precautions.
Maintenance of safety factor.
Summary.

To secure good coherence in an exposition it is necessary not only to arrange the material clearly and logically, but also to make the arrangement clear to the reader lest he plunge from one division into the next without realizing that he is taking up a new part of the composition. It is not alone sufficient that the arrangement be clear in the writer's mind; he must communicate the plan to his reader. A cataloguer who has classified and shelved the books in his library knows just where each division begins; a stranger in the book-stacks, however, would have great difficulty in determining what classification had been made were it not for the various labels and guides which direct him to the different sections. Lest the reader be lost in the composition, the writer must similarly direct him on the course.

This guiding of the reader is accomplished by what are usually known as *transition devices*, hints worked into the first, or near the first, of a new division, which convey to the reader the information that the writer has finished what he has to say about the part of the subject with which he has been dealing and is ready to go on to another division. Usually a transition sentence consists of two parts; the first echoes the division just completed, and the second announces the new division. Such a device is illustrated in the following sentences:

"Although easier to handle than the folding camera, the box camera is much inferior in the quality of the work which it does."

"Even more interesting than the developing of the plate is the next step in the process of making a photograph, the printing of the picture."

It is easy to see from these two sentences both the subject of the division just completed and that of the division being introduced. Sometimes a mere word or phrase is enough to show that a change of subject is occurring, and sometimes, where the divisions are very distinct and are announced clearly in the first sentence of each division, no transition *device* is necessary at all. To avoid monotony and stiffness it is always well to vary the devices used. But whatever device is employed, each change of subject should be at once apparent to the reader; he should always know just up to what point in the paper he has arrived.

Of the cardinal principles governing the planning and writing of the composition as a whole *unity* and *coherence* have so far been explained and illustrated. There still remains to be considered the principle of *Proportion*, which directs that the relative length of the different parts of a composition be made to correspond to the relative importance of the subject-matter of the divisions. Of the three principles considered this is the least important and the most easy to follow.

To get good proportion in his composition the writer must be careful to write everything to scale; that is, he must be careful to make the length of each division correspond, in general, to its importance. Ordinarily, proportion takes care of itself, for it is natural to develop most fully those divisions of the subject which are the most important. Sometimes, however, the writer may find himself in possession of more information on a relatively unimportant division than he has on a relatively important one, and if he is not careful, he will over-develop the unimportant division. The obvious method of avoiding this error is for him to increase his knowledge of the important division; if he does not do this, the reader is likely to get a badly distorted conception of the relative values of the two divisions.

One final word needs to be said about the application of the principles of unity, coherence, and proportion. No amount of study of abstract principles will in itself make a writer of any man. Men learn to swim by swimming, not by reading books on the art. And they learn to write very largely by writing, and no study of principles, deduced from the successful writing of other men, will assist a writer unless he tries consciously to use them or unless he absorbs them so completely that he employs them unconsciously.

It should be remembered, moreover, that each composition presents to a certain extent a new problem which no one has faced before. For this reason the general principles explained must be used intelligently in relation to the problem presented. Intelligently employed, they will assist in giving to the writing of any man the effectiveness which they have given to the writing of others.

Some special problems which still remain to be considered with the explanation of the general principles of planning and writing the whole composition are the title, the introduction and conclusion, and the literary style.

The Title

The title is the name of the composition; like the label on a bottle it should indicate the contents. It is the first part of an article which the reader sees and very often that which remains longest in his mind. For these reasons a careful selection of a title is more necessary than the writer usually imagines.

Readers ordinarily depend upon the title in deciding whether or not to read a given article, and the writer whose title is ambiguous or inaccurate in its indication of the subject-matter misleads his reader. The title should, moreover, be brief; usually it need only suggest the general subject, not give all of the details considered. It should indicate the point of view of the writer; there is a great difference, for example, between *How to Lay a Concrete Sidewalk*, which suggests directions to a workman, and *How a Concrete Sidewalk is Laid*, which suggests a mere explanation of the process. In addition to being given all these essential qualities the title can usually be made pleasing and attractive. *A Novel Method of Street Lighting* is a more attractive title than *Lighting a Street by Arches Fitted with Incandescent Lamps;* the second title gives more than is necessary of the subject and is much clumsier than the first. *Keeping in Touch with Construction Work* is a much neater and more attractive title than *A Suggested Method for Getting Reports and Keeping Records of Construction Work.* The titles of the technical articles in Part II will serve as further illustrations.

The Introduction

The self-conscious formality with which the average writer approaches the important and terrifying task of writing down his ideas for the inspection of a critical world is nowhere more in evidence than in the ponderous and irrelevant *introduction* which usually prefaces an article. The notion sometimes exists that the introduction, like the overture before the curtain goes up, has no real connection with the subject of the paper. Writers accordingly begin their papers with matter which has often only the remotest connection with their subjects. Usually the tendency is to bring in the ancient history of the machine or process described. The practice, too, is quite frequent, especially in an address, of attempting to put the audience in a pleasant frame of mind by relating a story or jest. This is sometimes legitimate where the anecdote has a definite point and can be immediately and easily connected with the subject under discussion; where, however, like the auctioneer's bell, it is a mere trick for getting the attention of the audience, it becomes cheap clap-trap. Concerning this general tendency to write irrelevant introductions the *Suggestions to Authors* of the American Institute of Electrical Engineers says:

"The tendency to preface a paper with a long and burdensome prelude, not intimately related to the subject under discussion, is very prevalent but should be avoided, as the introduction of unnecessary or irrelevant matter detracts from the value of a technical paper."

It should never be forgotten that the introduction, then, far from being a mere flourish at the beginning, is as regular and legitimate a part of the article as is the body or argument proper. What, then, may it contain? While it is impossible, of course, to give specific suggestions for all cases, there are certain elements which should be found in almost all introductions of papers of any complexity and length.

There should be, first of all, a clear announcement of the subject so that the reader may know from the start what he is reading about. This announcement need not be bald and unattractive. Such stiff introductory sentences as, "It is the purpose of the writer of this paper to call attention briefly to some special considerations arising from the recent failure of the concrete dam at Riverfield, California," and, "This paper aims to describe a new method of air analysis" are effective as announcements but awkward in expression. It is much better to begin with some positive and interesting statement which will serve at once to introduce the subject and to give an impulse to the development of the thought. The first sentence above, for example, might be rewritten as follows: "The recent failure of the concrete dam at Riverfield, California, presents, because of the experimental nature of a part of the construction, some problems of particular interest to the hydraulic engineer." The following initial sentence of a short descriptive-exposition is at once simple and effective: "The most efficient and practicable waterwheel to use where a small flow but a high head of water is available is the impulse wheel." The announcement need not occur in the very first sentence. Sometimes it is better to lead up to it as in the following introduction from a paper entitled *Running a Line over a River*:

"The surveyor, especially the railroad engineer, often has to find the exact distance from one place to another. Ordinarily this distance is accurately measured with a graduated steel tape in a straight line between the two points. Very often, however, some obstruction, such as a river, prevents the taping of the distance, and so the engineer has to resort to some indirect taping and some computation in order to get the distance of the line."

In addition to the announcement of the subject the introduction should contain, excepting in very short articles, some indication of the limitations of the subject and of the arrangements of the various parts. These elements in an introduction assist the reader to an understanding of the scope and method of the article in much the same way that the table of contents of a book assists him in understanding the scope of the book. The following introduction from an article on *The Strength of Cement Mortar* illustrates this principle:

"The strength of cement mortars is affected chiefly by (1) the proportions of cement used, (2) the size and grading of the sand, (3) the amount of water used, and (4) the degree to which the product is compacted. The effect of these factors may be summed into two general laws: (1) the strength increases directly with the proportion of cement used; and (2) the strength for a given proportion of cement increases directly with the density of the mortar. Law (2) expresses, in a general way, the effect of the sand, of the amount of water, and of the compactness of material."

Other elements which may be found in an introduction assist, in general, in clearing the ground for an understanding of the body of the paper. Among these are indications of the particular aim or subject of the writer, definitions of terms used in the paper, and all preliminary explanations which may be found necessary. To this last category belong such matters as, for example, the history of the development of a process where such an account would assist the reader in understanding the explanation of the modern process. But in all cases the writer must be careful to include in his introduction nothing which is not actually useful to his reader and relevant to his subject.

The Conclusion

It is difficult to begin a paper properly; it is sometimes even more difficult to close it properly. The writer who is convinced that he should introduce his paper with a flourish of trumpets is also certain that he should bow his subject formally off the stage. The best advice for him can be put briefly: "When through, stop." It is quite legitimate to sum up very briefly the points developed in a long argument; this assists the reader to get a brief review of the subject. Usually, however, such a summary is not needed, and any summing up which repeats the details of the discussion is an insult to the intelligence of the reader and a waste of his and the writer's time and energy. A graceful conclusion to the paper, which takes away the bluntness of breaking off short, can be devised without a vain repetition of ideas which the reader already has clearly in mind.

A conclusion, then, which is simply a formal tag to the composition and which merely repeats details which have already been made clear is quite useless. An examination of the end of a long exposition or argument will usually show, however, that the writer has had to say by the way of conclusion something which is not a part of the body of the article, but which has, nevertheless, an important relation to it. Such conclusions take a variety of forms. In a long argument, for example, the writer may emphasize the value of his reasoning by establishing in the conclusion the fact that he has taken an unprejudiced view of the question. A writer, again, who has been explaining, let us say, a social or economic condition, may conclude with a hint at the probable results of the condition of affairs which he has outlined. Technical descriptions and explanations of processes sometimes end with a statement of the personnel involved, the name of the inventor and manufacturer, or of the constructing company and engineers being given.

Such a conclusion has obviously nothing directly to do with the body of the article, but it is, nevertheless, of interest to engineers. The technical articles in Part II provide other examples of typical conclusions.

Style

Style in writing can not, of course, in its finer qualities be taught. A so-called *good style*, by which is meant a style that is facile, smooth, clean-cut, graceful, varied, and otherwise rich and pleasing, is the result of inborn ability corrected and chastened usually by long-continued reading of the best in literature. In the writing of technical papers the chief quality to be desired is, of course, clearness; it is of the first importance that the reader understand what has been written. The qualities of ease and grace of expression, the qualities which make an article pleasing to read, are, however, by no means to be despised. To assist in obtaining them every writer of technical papers should cultivate the habit of reading good literature, not only well-written technical books and articles, but also the best that the English language has to offer him in other fields. Many a professional man who has never had an academic training owes his facility in writing to his habit of careful, selective reading.

Although the subtler elements of good style can not be gained by conscious effort, there are two elements which can be consciously sought and which add greatly to the quality of clearness. They are conciseness and concreteness. Most men say too much; few men say too little. Most writers occasionally bury their thought under an avalanche of verbiage, using ten words where five would do. They need to acquire the habit of pruning mercilessly, of cutting off phrases which they can do very well without. "Steam engines," writes one, "may in general be divided into two classes. The first class is that of the reciprocating type, and the second class is that of the turbine type." How much more concise and effective if he had written simply, "Steam engines may be divided into two general classes, the reciprocating type and the turbine type."

An even more important habit to acquire is that of concreteness. The preference for the specific and concrete over the general and abstract results in clearness and color in the exposition. It is very easy to leave an idea vague and unintelligible for want of illustration; it is almost impossible, on the other hand, to over-illustrate. Specific examples, comparisons, and analogies should, therefore, be used freely wherever the ideas are abstract and likely to be difficult to grasp. All such comparisons and illustrations should be carefully adapted to the understanding of the reader. An American, for example, who is explaining the game of baseball to an Englishman can perhaps do no better than to compare it to the game of cricket. An engineer in describing to another engineer a machine with which the listener is not familiar will naturally compare it with a better known machine which it resembles; if, however, he is attempting to describe the same machine to a society girl, he will have to alter his comparison. In general, the examples and analogies may be safely drawn from the experiences of daily life with the assurance on the part of the writer that they will assist the average reader in his understanding of much which without them would be only vague and indefinite.

CHAPTER IV

THE PARAGRAPH

Introduction

If a composition were to be presented to the reader in a solid mass, with each margin in a straight, unbroken line and no indication whatever of the underlying scheme of organization, it would probably seem to him like a hopeless wilderness of ideas through which it would be tiresome if not impossible to find a way. To prevent this feeling a composition is always broken up into divisions called paragraphs. Each paragraph is set off distinctly by being begun on a new line, which is indented conspicuously from the left-hand margin. The aim of paragraphing is in general to make the composition clearer and easier to read.

Paragraphing may be done for a variety of specific reasons. Sometimes it is a mere visual device to assist the reader to pick up an idea quickly or to make one statement stand out clearly from others which surround it. Such is its use in a report, for example, in which each one of a series of recommendations is, for distinctness, paragraphed separately, and in a letter in which each item of an order for goods is marked out by separate paragraphing. Quotations, moreover, are usually paragraphed separately to distinguish them from the surrounding text. Besides these special uses as a visual device paragraphing serves the twofold purpose of breaking up a compositional mass, which without it would be hard to read, and of showing the reader where the different thought divisions of the composition occur. It is this last kind of paragraphing which will be considered in the present chapter. In a study of the paragraph as a division of the whole composition two questions immediately arise for consideration: first, where are the paragraph divisions to occur? and, second, what shall be the internal organization of the paragraph? These will be taken up in the order named.

Paragraph Division

Paragraphing has, it was pointed out, a twofold purpose: first, by breaking up the compositional mass into parts, it serves to make the composition easier to read; second, it serves to assist the reader in perceiving the underlying plan of the whole composition. The first of these purposes affects the absolute length of the paragraph; the second affects the content.

An examination of the paragraphs in a number of expositions of different types will reveal considerable variety in paragraph length. A comparison, for example, of the paragraphing of an editorial in a newspaper which caters to "the people" with that of an article in *The Atlantic Monthly* will show that the paragraphs of the editorial are, for obvious reasons, much shorter than those of the *Atlantic* article. Between the paragraphs of expositions which present less contrast there is, however, less difference to be noted, and an extended study of paragraph lengths will show that convention has set an approximate limit in both directions to the length of the paragraph. It is a part of the duty of the paragrapher to conform with this convention, which represents, after all, the best practice for the reader, by preventing paragraphs that are either so short as to be choppy or so long as to be tiresome.

An investigation of paragraph length in a number of well-paragraphed technical articles revealed the fact that in ordinary technical writing the paragraph very seldom runs over four hundred words or under one hundred. A paragraph over four hundred words seems too long; in most places where such paragraphs occur they may be broken up into two or more paragraphs without defeating the second aim of paragraphing, the indication of thought division. Conversely, paragraphs which run under one hundred words seem choppy and may in most cases be easily combined with other paragraphs. The average length is about one hundred and seventy-five words. In ordinary technical exposition, then, four hundred words, or thereabouts, should represent the upper limit of paragraph length, and seldom should the paragraph run under one hundred words. It should be remembered, of course, that these lengths relate only to paragraphs which occur in expository writing as distinct parts or units of the whole composition and not to paragraphs of the other types mentioned.

The question of the absolute length of the paragraph, a matter determined largely by conventional usage, is not as important as that of its content. Paragraph dividing is not a matter of measuring off parts having an average length of one hundred and seventy-five or two hundred words; the mere indention of the line marks the paragraph but does not make it. If the reader is to feel that the paragraph is of assistance to him in his understanding of the organization of the whole composition, the writer must make the indentions only when he has completed a definite phase of the subject; in other words, each paragraph must take up and develop one distinct part of the whole; it must be just as unified within its own limits as the whole composition is within larger limits. The chief difficulty in paragraphing is in determining just how large a division of the whole or how small shall be included within the paragraph limits. No fixed rule can be given; the writer should, however, in all cases avoid choppy paragraphing by selecting as his paragraph subject such a part of the whole idea as is capable of some development, and he should avoid overflowing his paragraphs by being careful not to put into them two or more phases which could more conveniently and easily be developed in separate paragraphs. Between the writer's working outline and the paragraph division there is no fixed relation. In a short exposition it is possible for each major division of the subject, as shown by the outline, to be developed within the limits of a single paragraph. In a long exposition, on the other hand, the major division may need several paragraphs for its complete development, each one taking up a subdivision of it. The idea, therefore, that it is possible to determine in each case from the working outline the exact number of paragraphs necessary is erroneous.

The relation between the outline and the problem of paragraphing and the principle of unity or singleness of subject in the paragraph can best be illustrated by a concrete example. Let it be assumed that the same writer has been asked to write two expositions on the subject *How Photographs Are Made*, the first a very brief explanation of nine hundred words or thereabouts and the second a short pamphlet. His outlines and the corresponding paragraphs might be as follows:

Exposition I

(900 words)

Introduction:

A. Definition of photography.

B. Description of the camera

(1 paragraph of 150 words).

Body:

I. Making the exposure (1 paragraph of 200 words).

II. Making the negative (1 paragraph of 300 words).

III. Making the print (1 paragraph of 250 words).

Exposition II

(30,000 words)

Chapter 1. Definition of photography and explanation of the chemical principles involved (15 paragraphs).

Chapter 2. Description of the camera (20 paragraphs).

Chapter 3. Making the exposure (25 paragraphs).

Chapter 4. Making the negative (40 paragraphs).

Chapter 5. Printing (35 paragraphs).

It will be observed that the outline of Exposition I is in relation to the length of the article fuller than the outline of Exposition II, but that the major divisions of the two outlines correspond.

Paragraph 4 of Exposition I might be written as follows:

1. Even more entertaining than making the negatives is the last stage, that of making the prints. 2. The chemical principle involved here is the same as in the making of negatives, the action of light on a sensitized surface; in printing, however, the sensitized surface is not on glass or celluloid but on paper, and the result is not a negative but a positive image. 3. Printing may be done in a variety of ways and on a variety of papers; the process of printing by artificial light on "developing papers" will be here explained. 4. The baths are prepared exactly as in the process of developing plates

by hand. 5. When all are ready, the light is dimmed, the negative is put into a "printing frame," which resembles a small picture frame, the sensitized side of a sheet of the printing paper is placed next to the negative, the back of the frame is clipped on, and all is ready for the "exposure." 6. This consists in allowing the light to shine through the negative upon the sensitized paper for a length of time dependent upon various conditions. 7. After exposure the paper is removed from the frame and immersed in the developing bath until the images appear clearly. 8. After being rinsed in water, the print is thrown into the "hypo," or fixing bath, where it is allowed to soak thoroughly. 9. Next it is washed for at least half an hour in running water, or in several changes of water. 10. Drying face down on a cloth surface or between blotters completes the process.

An analysis of this ten-sentence paragraph shows it to be made up of the following divisions:

Sentence 1. Link with the preceding division, and announcement of the new paragraph subject.

2. Statement of the principle involved in printing.

3. Announcement of the limitations of the paragraph subject.

4. Preparing the chemical baths.

5. Loading the printing frame.

6. Making the exposure.

7. Developing the print.

8. Fixing the print.

9. Washing the print.

10. Drying the print.

Sentences 1 to 3 here together form the introduction of the paragraph; sentences 4 to 10 together form the body. Each sentence in this latter group contributes toward the development of the paragraph subject, *making the print;* each one is, however, so manifestly slight in itself that it would be absurd to think of it in its present form as long enough for a separate paragraph; and to break the paragraph up, therefore, into as many subdivisions as there are subjects announced in the sentences would be to paragraph very badly. When, on the other hand, the total length of the exposition is considered and the consequent amount of development possible for this one thought division, it will be seen that the making of the print does very well as the subject of a single paragraph. It should be noted, incidentally, that the paragraph is only slightly longer than average.

In Exposition II, it will be observed, paragraph 4 of Exposition I has been expanded into a 35-paragraph chapter. Here each one of the sentences of paragraph 4 has been so developed as to become no longer a mere tributary to the development of the paragraph thought, but an independent subject of one or more paragraphs, having in its turn subordinate details which develop it. Sentence 6, for example, *making the exposure*, which in Exposition I is a mere announcement of a process detail, becomes the subject of a considerable exposition, in which such matters as printing frames, intensity of light, relation of density of negative to length of exposure, "dodging," the making of enlarged prints, etc., are given full consideration, each, perhaps, as the subject of an individual paragraph or of a group of paragraphs. Thus the subject of paragraph 4 becomes in Exposition II the subject of an entire chapter, and each detail, too slight and undeveloped in the first exposition to be regarded as a subject for an entire paragraph, expands into a paragraph or even becomes the subject of a considerable group of paragraphs, one of the major divisions of the chapter.

The foregoing explanation illustrates the problem of paragraph division as it applies to explanations of processes. In descriptive-exposition the principles are identical, the difference being only in the type of subject matter involved. This may be simply illustrated from paragraph 1 of Exposition I and chapter 2 of Exposition II. The description of the camera in paragraph 1 would, of course, be very short, a mere outline. The camera might here be described as follows:

* * * The instrument used in the ordinary processes of photography is the camera. Cameras are of various types, but all are operated on the same essential principles, and each consists of a light-tight box with an aperture at one end that is fitted, excepting in "pinhole" cameras, with a lens to produce a sharp definition of the projected image and a shutter to control the admission of light. * * *

This brief outline, which could not very well be much longer in the short exposition of which it is a part, would become in Exposition II an entire chapter in which each detail would be considerably expanded. The lens, for example, merely mentioned in Exposition I, might become the subject of a long explanation, with a paragraph or more devoted to each important type of lens.

Expositions in which the subject-matter is more abstract and the order of arrangement more arbitrary than in descriptive-expositions and expositions of processes are governed by the same essential principles of paragraph division. In such expositions, however, the subject of the paragraph is not a part of a machine described or a detailed step of a process, but, usually, a single "point" or division of the whole thought. An exposition of about a thousand words, for example, on *Requirements of a Good Electrical Testing Laboratory* might have five paragraph subjects as follows:

Paragraph 1. Introductory: The value of a good testing room.
2. Good location.
3. Adequate equipment.
4. Efficient management.
5. Good permanent records.

Each paragraph subject here is big enough for development within the limits of a paragraph of the average length. In a much longer article on the same subject the details of each paragraph would expand into full paragraph subjects.

An attempt has been made in the foregoing explanation to demonstrate that good paragraphing comes from an observance of the conventional usage which has set the approximate limits to the actual length of the paragraph, and even more from the development within the limits of the paragraph of a single part or phase of the whole composition. It follows that any intrusion into a paragraph of a detail which does not contribute to the development of the central thought or paragraph subject is a palpable violation of the second and more important of these guiding principles. Such a violation can come only from careless planning of the whole or from a failure to guard the integrity of the paragraph. The following careless paragraph from a description of a waterwheel shows the tendency to put together into a single paragraph material which should be paragraphed separately:

"The cups around the circumference of the wheel are oval; the reason for this form of cup is that it results in more pressure than can be obtained from any other form. Just why this should be so can be seen from the sketch, which shows that the impinging stream transmits two forces on each half cup, the first created when the water hits the cup, and the second when it leaves the cup. The cups are so arranged that the stream will always strike a cup in any position of the wheel and secure a maximum leverage for such a position. *The wheel is mounted on a shaft on one end of which is a pulley. The head of water at the nozzle used for these wheels varies from about twenty feet to as high as can be obtained, and the horsepower developed ranges between one and one-hundred.*"

The subject of this paragraph is clearly *the water-cups*, and the statements in the italicized sentences relating to the mounting of the wheel, the head of water used, and the horsepower developed have no business here; they are misplaced details which should be doing duty in other paragraphs. Similar violations of the unity of the paragraph occur in any paragraph in which there are details that do not belong to the central thought or paragraph subject.

Internal Organization of the Paragraph

The handling of the details of the paragraph in such a manner that they develop the central thought clearly is a problem partly of logical arrangement of the details, partly of making their relationship immediately evident to the reader by a careful indication of their connection. There is no universal method of arrangement to be followed in organizing a paragraph; the plan of each paragraph, like the plan of each whole composition, is to a certain extent peculiar. It is possible, however, to give general suggestions which will almost always assist the writer to secure a clear organization of his paragraph material.

An analysis of any well-written expository paragraph will show it to possess a central thought and certain details which serve to define and elucidate the central idea and enrich it in its meaning or application. In organizing a paragraph it is usually best for the sake of definiteness and clearness to indicate the subject of the paragraph, the central thought, definitely at the beginning, either in the first sentence or very soon after it. Such an initial step means that the reader knows at once what phase of the subject he is about to take up; on the other hand, not to make such a definite announcement results in the reader's receiving a very vague and uncertain impression of the central idea. This announcement, or, as it is sometimes called, *proposal* of the subject, is to the paragraph what the writer's announcement of his whole subject in his general introduction is to his whole composition; its omission results in both cases in the reader's groping for a central thought, for a *container*, so to speak, of the ideas which follow.

In certain types of paragraph, of course, it is desirable and at times even necessary to state the subject of the paragraph last instead of first. This is true of all paragraphs in which the central idea would be unintelligible without considerable preliminary development. An abstract proposition, for example, might mean nothing whatever to a reader until he has been led up through a careful series of concrete illustrations to understand it. This type of paragraph does not occur, however, very frequently in ordinary technical composition; in the majority of cases the clearness of the paragraph is best served by a definite indication at the beginning of the subject to be developed.

Following the announcement of the paragraph subject there may be some necessary definition or limitation of it, or for added clearness it may be restated in another form. This part of a paragraph is by no means always essential. It is most likely to occur in exposition of ideas rather than in exposition of concrete facts.

After the subject announcement and subject definition which sometimes follows come naturally the details which develop the central thought. Such details, of course, vary widely in their nature. In a paragraph from a descriptive-exposition, for example, where the paragraph subject is, let us say, one part of a machine being described, the details will give the appearance of this part, its mechanical construction, function, relation to parts previously described, etc. In a paragraph from an exposition of a process, where the paragraph subject is, perhaps, a minor step in the manufacture, the details will naturally explain this step from point to point and possibly give its relation to the entire process. A paragraph from an exposition dealing with ideas which are more abstract will have its central thought developed by definition, evidence, citations of authority, examples and illustrations, comparisons, etc., in almost unending variety. No principle for their logical arrangement can be given; in each paragraph the writer must determine what order will best bring out the central thought or paragraph subject.

In descriptive-expositions and explanations of processes the paragraph usually ends with these developing details. In expositions dealing with more abstract material, however, the details are frequently followed by other material, some comment, it may be, on a proposition which the paragraph has aimed to establish, or a restatement in some emphatic form of the idea developed. Just when it is necessary or advisable to add this final element must be determined for each individual paragraph.

The following diagram of a typical paragraph and summary of the suggestions given for paragraph organization may help to make the principles clearer. The numbers refer not to sentences but to elements in the paragraph. The arrangement given here, as has been pointed out, is by no means universal; it is, however, in technical writing by far the most frequent.

1. Link with preceding paragraph or division (often combined with 2.)

2. Announcement of the paragraph subject.

3. Details developing the paragraph subject and forming the body of the paragraph.

4. Occasional comment on idea developed.

Solidity and compactness of the paragraph result very largely from a careful attention to the form of the individual sentences and a careful arrangement of all the details. These qualities result also very largely from a deliberate binding together of the sentences by various transition devices. The importance to the clearness of the whole composition of those sentences which serve to bind the different paragraphs together was pointed out in the preceding chapter. Within the paragraph, too, there are similar links between sentences and groups of sentences which serve to indicate the interrelationship of parts and to make the whole paragraph solid and compact. Such devices may consist of a phrase in which the idea of the preceding sentence is picked up and carried on, or of a word indicating that one sentence contains an idea that is in sequence with that of a preceding sentence (*first*, *secondly*, *next*, *afterward*, *then*, etc.), is added to it (*moreover*, *again*, *also*, *furthermore*), contrasts with it (*however*, *nevertheless*, *in spite of*, *yet*), is the result of it (*therefore*, *consequently*, *accordingly*), or stands in some other relation to it. Often, especially when in the development of a central thought a number of similar ideas are introduced, mere similarity of sentence structure will indicate that the sentences have the same function in the paragraph, and no specific transition device need be used. In all cases care should be taken to use the device which best indicates the thought relationship between the sentences concerned, and to avoid falling into the habit of monotonously using one transition device to the exclusion of others. The lack of clearness which may result from their complete exclusion is well illustrated in the following paragraph. This paragraph possesses unity, since it deals with but one phase of a larger subject, but so carelessly have the details been handled that the impression is indistinct, and the ideas seem out of focus.

1. The first important consideration in electrification is, can the same or better service be obtained with electric locomotives than with steam locomotives? 2. It has been shown in nearly every case where it has been tried that electrification improves the service considerably. 3. Electric locomotives are in their infancy as compared with steam locomotives, and yet the former have reached seemingly the highest point of perfection. 4. At present the best types are operated at 92 per cent. efficiency from third rail to rim of drivers, maintained in original operating condition at a cost of 3 cents per mile, and required

to be inspected only after 1,200 miles of operation. 5. Steam locomotives are not nearly as efficient, and have to be continually overhauled and repaired, and will stand much improvement. 6. With the use of the superheaters, stokers, etc., their efficiency is being gradually increased. 7. The time used by the steam locomotive in taking on coal and water and changing engines is done away with by the use of the electric locomotives, since the latter may be run continuously. 8. A considerable loss of coal is involved when each locomotive is run independently of the others, as the steam locomotive. 9. Experiment has shown that about 10 per cent. of the amount of coal consumed is used in the actual moving of the trains. 10. The rest is used in firing up, standing on the sidings and in the round-house, coasting down grades, for banking, etc. 11. In the electric locomotive the electric brake may be used, thus saving overheating of the car wheels caused by the friction of the brake shoes upon them when the automatic air is used.

Many of the sentences in the paragraph are absurdly faulty in construction; we will, however, confine our attention to the paragraph as a whole. The paragraph thought is apparently "Electric locomotives are superior to steam locomotives." A very close scrutiny will show that the writer has three reasons in support of this proposition: Electric locomotives are superior to steam locomotives because (1) their operating efficiency is higher, (2) they are more economical in (*a*) time and (*b*) coal, and (3) they use the electric instead of the air brake. These three "points" have, however, been run together with no attempt at marking the separation. Moreover, many of the sentences have been written with no apparent regard for the development of the central idea;

sentence 6, for example, is as it stands a clear argument for the steam locomotive. In the following rewriting of the paragraph an attempt has been made to bring out the central thought more clearly.

1. When a railroad company considers the electrification of its road, the first and most important question to arise is: Do electric locomotives give better service than steam locomotives? 2. The evidence shows that in nearly every case where electrification has been tried, they do give better service. 3. In the first place, in spite of the fact that they are still in their infancy as compared with steam locomotives, they are much more efficient in operation. 4. The best types are now operated at 92 per cent. efficiency from third rail to rim of drivers; they are, moreover, maintained in their original operating condition at a cost of only 3 cents per mile; and they need inspection only after 1,200 miles of operation. 5. Steam locomotives, on the other hand, in spite of the fact that superheaters, stokers, and other mechanical devices are gradually increasing their efficiency, are not nearly as efficient; moreover, they have to be continually overhauled and repaired; and they need very frequent inspection. 6. In economy, as well as in mechanical efficiency, the electric locomotive is superior to the steam locomotive. 7. The electric locomotive is a time saver in that it does not, like the steam locomotive, require coaling, taking on of water, and changing of engines. 8. It is economical also in fuel saved. 9. The steam locomotive, because unlike the electric locomotive it is an independent generator of energy, actually uses in moving its trains only about 10 per cent. of the total coal which it consumes; the rest is used in firing up and banking, and while the locomotive is standing idle on

sidings or in the round-house, or is coasting down grades. 10. The electric locomotive has another advantage in its use of the electric brake instead of the automatic air brake, since the latter results in frequent overheating of the car-wheel rims from the friction caused by the brake shoes. 11. Under actual operating conditions, therefore, there can be little doubt of the decided superiority of the electric locomotive.

An examination of the following paragraphs with the brief analysis following each will fix more firmly in mind the principles of paragraph construction which have been explained. The paragraphs have been purposely selected from the usual types of technical exposition, and present no particular peculiarities of form. A further analysis of paragraphs selected at random from the examples of technical composition in Part II of this book will be found a valuable exercise in studying the paragraph.

I. 1. The main piece of apparatus, remarkable alike for the simplicity of its construction and the range of its performance, is the annunciator. 2. In the earlier forms of the alarm, the indications were made by means of a simple switchboard provided with buttons bearing the names of the apartments protected. 3. When an alarm sounded, the depression of each of these buttons in turn until the bell ceased ringing was necessary to determine its locality. 4. This is still quite largely used as it is cheaper than the more perfect annunciator which tells at a glance where the disturbance in the circuit is. 5. In shape and size this latter instrument resembles an ordinary mantel-clock. 6. The indications are given by devices on the face, which vary with different makers. 7. In one form they are made by arrows, which lie horizontal when in normal position, and point to the names of the apartments printed above them when indicating. 8. In another form cards drop down in front of apertures arranged in rows on the face, and in still another the name and number of a room are uncovered by a falling piece when an alarm is sounded. 9. The needle instrument is shown in Fig. 1. 10. Once made, the indications remain until the parts are restored by some one. 11. A small switch at one side completes or opens the circuit through the instrument, and one on the other side controls the connection with the bell. 12. A row of studs at the base of the apparatus allows any opening to be disconnected that may be desired. 13. Aside from its giving an alarm when an attempt is made to enter a building, the annunciator has an important use in showing when a place is properly closed. 14. If any window or door has been forgotten, it will infallibly point it out. 15. In large business houses where there are many openings this feature is of the greatest value. 16. By disconnecting the bell, this test can be made a silent one.

Sentence 1. Subject of the paragraph, the annunciator, and announcement of points to be emphasized: (1) the simplicity of construction; and (2) the range of performance.

2–4. Description and operation of early types.

5–12. Description and operation of various later types.

13–16. An additional use of the annunciator illustrating the "range of its performance."

II. 1. The pendulum consists of a 12.2-inch (30.9-centimeter) United States Army mortar, weighing 31,600 pounds (14,333 kilos), which was supplied by the Bureau of Ordnance of the War Department. 2. The mortar rests in a stirrup made of two machine-steel rods 1½ inches (3.8 centimeters)in diameter, each bent into a U shape. 3. The ends of each of these rods are passed through two cast-steel saddles, which fit over a steel supporting beam. 4. The supporting beam is 8 by 4 inches (20.3 by 10.2 centimeters) in section and 87 inches (221 centimeters) long. 5. This beam is provided with two nickel-steel (3 per cent. nickel) knife edges, which are countersunk into its lower face near each end (see Fig. 1). 6. The knife edges rest on bearing plates measuring 2 by 8 by 10 inches (5.08 by 20.3 by 25.4 centimeters).

Sentence 1. Paragraph subject, description of the pendulum, and general statement that a mortar was used.

2–6. Details of construction of the pendulum support.

III. 1. The testing gallery (Plates III and IV) was a rectangular boiler-iron box, 18 by 18 by 24 inches, provided with a glass door, two observation windows, and a circular opening 13 inches in diameter at the top of the box to relieve the pressure developed by an explosion. 2. This opening was covered by a sheet of paper coated with paraffin and held in place by a heavy iron ring. 3. The electrical connections were brought into the gallery through gas-tight bushings. 4. A sliding rod for breaking the lamps penetrated the side of the gallery through a gas-tight steel bushing.

Sentence 1. Paragraph subject, general description of the testing gallery; general appearance and parts.

2–4. Additional details of construction.

IV. 1. The actual process of developing a film is fairly simple. 2. First the film is unrolled and detached from its light-proof cover. 3. Then it is immersed quickly in the developer solution. 4. While in the solution, the film is kept constantly in motion to prevent uneven development. 5. After a few moments the picture begins to show up. 6. As soon as the development has gone far enough so that the outline of the picture may be seen clearly on the reverse side of the film, it is removed from the developer and rinsed quickly in water. 7. Next it is placed in the soda or "hypo" solution, where it remains until the milk-like deposit on the reverse side has been dissolved off, and the film appears perfectly transparent throughout. 8. The film is then washed thoroughly in running water for at least 30 minutes, and is finally hung up to dry. 9. After drying the film is ready for printing.

Sentence 1: Paragraph subject, process of developing a film.

2–9: Detailed steps in the process.

V. Method of Conducting Test

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* * * * * * * * * * * * * * * * *

1. The head of the cylinder is now removed. 2. One leg of a No. 7 electric detonator is fastened to the wire that passes through the insulated plug on the upper segment of the cylinder, and the other leg is grounded to the gage through the iron support with which it is in contact. 3. The detonator is inserted and secured in the cartridge, and the cartridge laid upon the wire support. 4. The head of the cylinder is then replaced. 5. The cylinder is now exhausted until the internal pres-

sure equals 10 millimeters of mercury, and the motor which operates the drum is set in revolution. 6. When everything is ready, the charge is fired by an electric firing device, and the indicator record is taken.

Paragraph subject, method of making an explosion test, is announced by the sub-title printed above the paragraph.

Sentences 1–6: Detailed steps in the process.

VI. 1. Trolley wires in mines present a most fruitful source of electric shock. 2. Trolley wires are necessarily bare conductors; they may extend for long distances throughout a mine, and often they must be installed less than a man's height above the track rail which is used as part of the return circuit. 3. A low trolley wire is especially dangerous in places where men must work in making up trips of cars, as at partings where loaded trips are brought out to the foot of a rope-haulage system. 4. Under such circumstances both the loaded and the empty trips are in the parting at the same time, and manipulation is required to make up the loaded trip to be taken out on the rope and to split up the empty trip to be taken in by the various locomotives. 5. It is often desirable to do this work rapidly, and if the trolley wires are lower than a man's head, the chance for shock is considerable. 6. Even if the men are familiar with the conditions, their attention, while hurrying to get the trips away from the parting, can not be constantly on the trolley wire.

Sentence 1: Paragraph subject, the dangers from trolley wires in mines.

2: General dangers.

3–6: Especial dangers of low trolley wires.

VII. 1. Several tests were next made to determine whether fuse could be made to "flash" under ordinary conditions of temperature and pressure, solely by constricting some points in its length. 2. Pieces of fuse of definite length were taken, and by means of pliers were held tightly at a number of points in such a way as to prevent the escape of gas beyond the constriction produced by the jaws of the pliers. 3. In these experiments a somewhat increased rate of burning was noted (82 seconds per meter, or 25 seconds per foot, as against a normal rate of burning of 92.5 seconds per meter or 28.8 seconds per foot), but in no case did the fuse flash entirely through or even for a considerable distance. 4. There was always a sharp report caused by the gases suddenly bursting through the side of the fuse, but this appeared to be simply a local phenomenon. 5. The break produced in the fuse provided at once an exit for the gases sufficient to prevent any further increase in the rate of burning. 6. When constrictions were placed every 2 or 3 centimeters along a piece of fuse, the rate of burning was not increased more than about 10 per cent.

Sentence 1: Paragraph subject, tests made of fuse constricted at arbitrary points in its length.

2: Method employed.

3–6: Various results observed.

VIII. 1. The general behavior of the lamps in the tests of series 1, 1–A, 1–B, 1–C, and 1–D was the same. 2. With three exceptions, the filaments of the standard lamps were broken when the bulbs were smashed, but the miniature-lamp filaments usually remained intact. 3. Ignitions, when they occurred in the tests of standard lamps, seemed to take place almost simultaneously with the blow of the breaking hammer, but in some of the miniature-lamp tests the ignition of gas was delayed until several seconds had elapsed after the bulb had been broken. 4. In most tests the bulb was practically destroyed by the blow. 5. In a few tests the breaking rod merely made a hole in the side of the bulb.

Sentence 1: Paragraph subject, general behavior of lamps under certain tests.

2–5: Details relating to breaking of filaments (2), ignitions (3), and damage done to bulb (4 and 5).

IX. 1. The word "liquid" as used in this discussion denotes all the forms of combustible between gaseous and solid; that is, such substances as in a strict physical sense are not gases or solids. 2. For example, if we pour some coal tar in its viscous semiliquid form into a hot coal fire, a very dense brown "smoke" will issue from it. 3. We know that this smoke is not gas; it is also hard for us to believe that all this smoke would consist of tiny, angular pieces of solid carbon. 4. It is perhaps easier to think that at least a part of the smoke is composed of minute globules of the tar which have been boiled off, somewhat like the visible "steam" coming out of boiling water. 5. For lack of better expression, we say that the combustible in the globules is in "liquid" form.

Sentence 1: Paragraph subject, definition of the word "liquid."

2–5: Specific example to illustrate the use of the word.

X. 1. In my opinion a patent covering the invention should not be applied for until the third stage is about 80 per cent. completed, and the experimenter knows with reasonable certainty that his process will work and that his apparatus has permanent value. 2. A patent drawn at this period is sure to be of real worth. 3. As the idea has passed through the three preliminary stages, it has undergone modifications and changes. 4. Now, however, it is a well-formulated, definite, practical fact, a thing to which the inventor is properly entitled to protection. 5. Such a patent is almost always obtainable and seldom vulnerable. 6. The invention has been developed logically and as rapidly as systematic work would permit; therefore it is unlikely that others who started later have overtaken the experimenter in this particular field. 7. Ideas hastily formulated and lightly patented seldom are sufficiently complete to be of value; consequently, interference from them is not to be greatly feared, especially if the statement of conception, made and recorded at the end of the first stage, is available. 8. Before the patent is issued, the third stage will have been completed, the design of the apparatus determined, its efficiency and durability demonstrated, and the construction of the Semi-commercial Plant begun.

Sentence 1: Introductory to announcement of paragraph subject.

2: Paragraph subject, a proposition to be established.

3–8: Points in support of the paragraph proposition.

CHAPTER V

THE SENTENCE

Introduction

The ability to construct a genuinely good sentence is much more rare than the ability to organize a whole composition or to plan a paragraph. The reason for this is not difficult to understand. The larger the unit, the more deliberately it may be dealt with; the smaller the unit, the more difficult it is to manipulate. A writer who may have considerable skill in arranging the divisions of a long exposition and even in planning a paragraph may still write very poor sentences because he has no fundamental knowledge of sentence structure or because he has not the art, and it is an art, of so grouping the details of his sentence that the result will be an effective expression of the idea which he wishes to convey. The sentence is usually so small a unit that it slips away from him; twist his idea how he may, he still finds the clear and vigorous expression of it baffling. Even when he has learned to avoid the pitfalls of sentence construction which is positively incorrect, he still may write sentences which are slovenly and weak, for the problem of good sentence-making is the problem not only of writing correctly but also of writing effectively. The price which must be paid for good sentences is constant vigilance and painstaking revision. No amount of drill in correcting the bad sentences of others can take the place of care in constructing and correcting one's own sentences. Such drill can, however, assist the writer to a better understanding of sentence construction; it can help him to get a better grip on his own ideas and to manipulate the elements of his sentences with more assurance and power.

In revising his exposition a writer should test his sentences from two points of view: he should make certain, first, that each sentence is correctly constructed and is as clear and vigorous as he can possibly make it; and he should make certain, second, that each sentence is doing its share in the development of the paragraph idea. This second test will determine, for example, whether a sentence is properly linked to other sentences, whether, perhaps, it is parallel in form with a preceding sentence which contains a coördinate idea, whether, in brief, it runs smoothly into the paragraph mold or is a misfit. The necessity of considering each sentence in connection with related sentences will appear from the following sentence group. At the left the ideas appear incorrectly divided into sentences and with the climax of the group, contained in the phrase "portable oxyhydrogen outfit," obscured and unemphatic; in the reconstruction at the right an attempt has been made to correct these defects.

Ineffective	*Improved*
In the erection of almost every large steel building or bridge, it is necessary that several of the steel parts or members be altered before they can be fitted together to make up the structure.	In the erection of almost every large steel building or bridge it is necessary to alter several of the steel parts or members before they can be fitted together to make up the structure;

Sometimes a member must be cut and sometimes two parts must be welded together, and a portable oxyhydrogen outfit is generally used to do this work.

sometimes they must be cut into different shapes, and sometimes two of them must be welded together. To do this work use is generally made of a portable oxyhydrogen outfit.

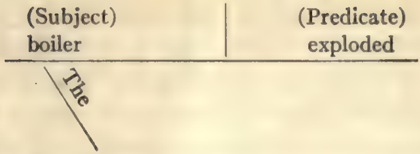
Most of these questions, however, although they affect radically the construction of any connected group of sentences, belong really to the study of the paragraph. This chapter on the sentence will, accordingly, be concerned with a study of the individual sentence, its construction and the defects to which it is liable. The plan to be followed will be to give first a brief explanation of the anatomy of the sentence, and then to take up in succession a number of the principles governing the construction of sentences which are clear, well-balanced, vigorous, and otherwise effective. The chapter does not aim to be a complete treatise on the subject; it aims merely to give a general understanding of the essential framework of the sentence and of some of the avoidable defects and errors in construction which are most likely to result in obscure and weak expression of ideas.

Grammatical Structure of the Sentence

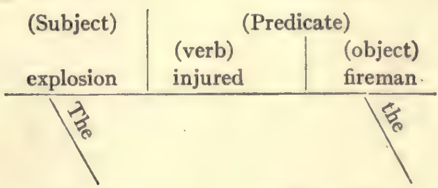
To define the sentence is not easy. The old definition of the sentence as the "verbal expression of a single complete thought" is vague inasmuch as the phrase "single complete thought" is not clear; a sentence, as every reader knows, may properly be very short, only a word or two, or it may just as properly be very long and contain not a single thought but a great many related ones. It is better, perhaps, to ask what elements are absolutely essential to make a group of words a true sentence. To this question there is a definite answer: every sentence must consist of at least one independent subject and predicate, that is, of a substantive—noun, pronoun, or word-group used for a noun—and a verb which asserts something of the substantive and which may or may not have an object. Such a subject-predicate combination, or *predication*, as it is called, is said to be *independent* when it can stand unsupported by any other predication; it is said to be *dependent* when it needs the support of another predication. Excepting for such expressions as "Fire," "Help," "Run," etc., where the idea appears in a shortened form, every complete sentence must contain at least one independent predication. Examples will make this clearer.

It is obvious that "The boiler exploded," short as it is, is a true sentence since it consists of a subject, "boiler," and a predicate, "exploded," and is independent of any other word-group. It is equally obvious that in the word-group, "The boiler exploded painfully injuring the fireman," the words "painfully injuring the fireman" can not, standing alone, be a sentence since they contain no subject and since the verb is not in the form in which it can be used in a predicate. Similarly, in the word-group, "When the boiler exploded, the fireman was painfully injured," the first part, up to the comma, can not by any possibility be made into a separate sentence since, although it has a subject, "boiler," and predicate, "exploded," it is clearly dependent upon the second word-group, and by our definition a sentence, to be a sentence, must be able to stand alone.

Diagrammatically the brief sentence which we have been examining may be represented as follows:



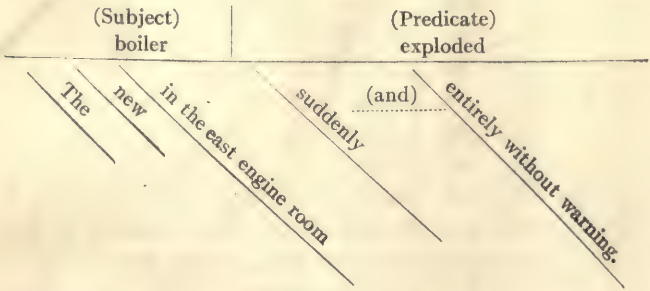
Excepting for such shortened constructions as have been referred to, "Fire," "Help," "Run," etc., this sentence is about as short as a sentence can be made. Often, as has already been indicated, the predicate is expanded by an object which receives the action of the verb; this invariably occurs with the so-called *transitive* verbs, which require an object to complete their meaning. Diagrammatically a sentence with subject and predicate consisting of both verb and object may be represented thus:



For the sake of simplicity, however, we will make use in the explanation which follows of the simpler form of a subject and a predicate consisting only of the verb.

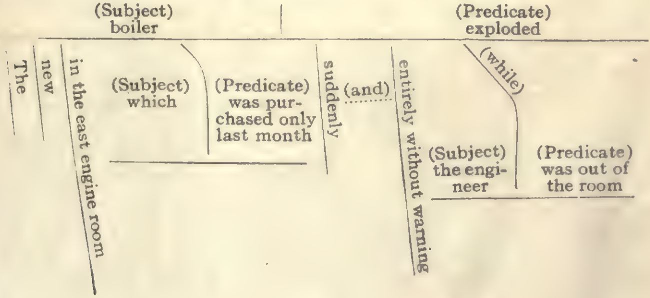
In the simple sentence as we now have it something definite is affirmed or "predicated" of the subject "boiler." Now, without making any further direct assertion about the boiler, we may add indirectly new ideas concerning it. Similarly, we may add indirectly to the ideas concerning the circumstances under which the explosion occurred. For example, we may write, "The *new* boiler exploded *suddenly*." In this sentence the word *new* is called an *adjective* because it is *added to* the noun which it qualifies; the word *suddenly* is called an *adverb* because it is *added to the verb* which it modifies. It will be seen that our expanded sentence, though still short, really contains *three* ideas—no longer a single one: these are (1) "The boiler exploded;" (2) "The boiler was new;" (3) "The explosion was sudden." Only one of these, the first, is, however, basic; the others are clearly subordinate.

But it is not only single words which may be added thus indirectly to both the noun-subject and the verb-predicate; groups of words may also become a part of the sentence. For example, we may write, "The new boiler *in the east engine room* exploded suddenly and *entirely without warning*." Diagrammatically this may be presented thus:



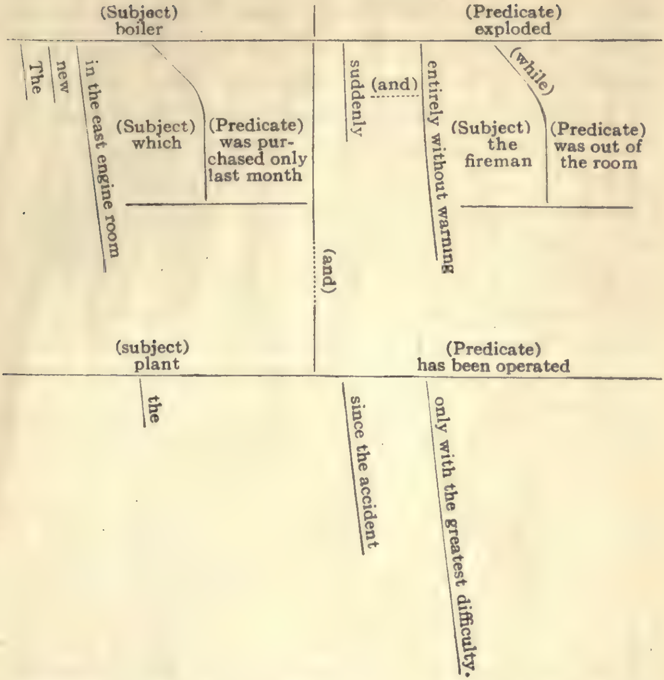
(In this diagram and in those which come later the explanation has been simplified by considering the modifying word-groups as wholes; no attempt has been made, that is, to indicate the relationships of words in any modifying word-group to other words in the same group.) The word-groups added to the sentence are called *phrases;* the first, because it modifies a substantive, is called an *adjective-phrase*, and the second, because it modifies a verb is called an *adverb-phrase.* A phrase contains no subject and predicate. It will be observed that more ideas have been added to the sentence, but that it still contains *only one* predication or subject-predicate combination. Such a sentence, no matter how many qualifying single words and phrases it may have, is called a *simple sentence.*

But it is possible to add to the sentence not only adjective- and adverb-phrases but adjective- and adverb-clauses. A *clause* is a word-group which contains a subject and predicate; when it is used to modify a substantive or a verb, that is, when it is either an adjective- or an adverb-clause, it is said to be *dependent;* when, on the other hand, it is not used as a modifier but can stand alone, it is said to be *independent.* It will be noted at once that the sentence with which we started, "The boiler exploded," is an independent clause; in this case it happens also to be a complete sentence. An adjective- and adverb-clause added to our growing sentence might make it read as follows: "The new boiler in the east engine room, *which was purchased only last month,* exploded suddenly and entirely without warning while *the fireman was out of the room.*" Diagrammatically this may be represented thus:



It will be seen that without in the least overburdening the sentence we have added still further ideas about the engine and concerning the circumstances attending the accident. It will be seen, too, that we have here not *one* predication, or subject-predicate combination, but *three*, the original independent one, "the boiler exploded," an adjective- or relative clause, as it is often called, "which was purchased only last month," and an adverb-clause, "(while) the fireman was out of the room." The *simple sentence*, it will be remembered, contained only one clause; we have here, therefore, a new grammatical type, the *complex sentence*. This is the name given to a sentence which contains *one* independent clause and *one or more* dependent clauses. In a complex sentence the independent clause is called the *principal clause*.

There remains one further grammatical type of sentence to explain, the compound sentence. A *compound sentence* is one which consists of two or more independent clauses. When in addition to these independent clauses, there are dependent clauses, the sentence is sometimes called a compound-complex sentence. A further expansion of the sentence with which we have been working will give us an example of this more complicated type. Thus expanded, the sentence might read, "The new boiler in the east engine room, which was purchased only last month, exploded suddenly and entirely without warning while the fireman was out of the room, *and since the accident, the plant has been operated only with the greatest difficulty*." Diagrammatically this may be represented as shown on page 85. The simple original statement, "The boiler exploded," has been very greatly expanded with words, phrases, and



clauses modifying both the original noun-subject and the original verb-predicate. Finally there has been added an independent clause which is connected to the original independent clause only by a coördinating conjunction, "and," a mere coupling-pin to hold the two parts together. And though in the process of growth the sentence has passed from simple to complex and from complex to compound, the central thought has remained the core of the sentence, made equal or coördinate in the sentence of the last type with a new independent idea; at no time has the sentence ceased to be an integer.

By the process of expanding a single, simple subject-predicate combination we have come to some realization of what a sentence is. It has been demonstrated that a combination of words in order to be a true sentence must have at least one independent subject and predicate; it may be very simple or it may be very intricate with a number of modifying words, phrases, and clauses, and even with independent clauses more or less closely associated with it. A summary of what has been said about the anatomy of the sentence and a review of the definitions which have been arrived at inductively during the course of the preceding explanation may serve to give a clearer understanding of sentence structure.

The elements which may enter into the framework of a sentence can best be shown in a simple table:

(Subject)	(Predicate)	
Noun or pronoun or phrase or clause used as a noun	verb	object Noun or pronoun or phrase or clause used as a noun
Adjectival elements: 1. Word (adjective). 2. Adjective-phrase. 3. Adjective-clause.	Adverbial elements: 1. Word (adverb). 2. Adverb-phrase. 3. Adverb-clause.	Adjectival elements:- 1. Word (adjective.) 2. Adjective-phrase. 3. Adjective-clause.

From this table the basic elements which compose a sentence are seen to be single words, phrases, and clauses. Of the single words the most essential are the *nouns* and *pronouns*, and the *verbs;* modifying the substantives are the *adjectives;* modifying the verbs are the *adverbs*. Other single words which play a part in the sentence are *prepositions*, which indicate certain relationships between words, *conjunctions*, used to join single words or word-groups, and *interjections*, mere exclamations introduced into the sentence usually without grammatical connection. All of these taken together are called the *parts of speech.*

A *phrase* is a word-group which does not have a subject and predicate. It may be used as the subject of a verb, as the object of a verb, as the modifier of a substantive, verb, or adverb.

A *clause* is a word-group which contains a subject and predicate. Like the phrase it may be used as subject or object of a verb or as an adjectival or adverbial modifier. It may be either *independent,* in which case it can stand alone and may even constitute a complete simple sentence, or *dependent,* in which case it must be connected with an independent clause and cannot be a sentence.

The grammatical classification of sentences into simple, complex, and compound depends upon the number of clauses within the sentence and the mutual dependence or independence of these clauses. A sentence which contains *a single clause,* which will, of course, be independent, is called a *simple sentence* no matter how many modifying single words or phrases it may have. A sentence which contains a *single independent clause and one or more dependent clauses* is called *a complex sentence.* Finally, a sentence which contains *two or more independent clauses* is called a *compound sentence.*

In the foregoing exposition of the anatomy of the sentence not everything that might be said about the grammatical structure of the sentence has, of course, been said. An attempt has been made merely to give such a general understanding of the essential framework of the sentence as is absolutely necessary for an intelligent consideration of the rhetorical principles of good sentence-making. It should be remembered that, grammatically speaking, any sentence is theoretically susceptible of indefinite expansion. Not only nouns and pronouns but phrases and clauses may be made the subjects and objects of verbs. Moreover, any substantive and any verb which is part of a qualifying phrase or clause may itself be modified by additional words, phrases, and clauses. To realize this and to have at all times a grip upon the essential structure of one's sentence is fundamental in good sentence-making. With the foregoing explanation of the grammatical structure of the sentence as a basis, we are the better prepared, then, to turn to the principles which underlie the construction of sentences which are not only correct but clear and vigorous.

Punctuation

Punctuation is the art of indicating by a system of marks or points the relationships of the elements in written discourse. Without its help the reader would often misunderstand the relationship of one thought to another. How necessary in some cases it may be will appear from the following two sentences, which are, it will be observed, identical excepting for the punctuation:

The student who believes that punctuation is unnecessary says the teacher of punctuation is a fool.

"The student who believes that punctuation is unnecessary," says the teacher of punctuation, "is a fool."

Now it does not often happen that the mere punctuating of a sentence will so completely change the meaning; it happens very often, however, that mispunctuation, or the failure to punctuate at all, results in ambiguity or general obscurity. The misplacing or omission of a single comma in legal documents has more than once led to differences of opinion and costly litigation. It behooves the writer, therefore, to make the best possible use of this device for making his ideas clear. Modern practice is opposed to over-punctuation; but modern practice does not sanction the inclusion or omission of a punctuation mark where such misuse or neglect would confuse the reader.

Inasmuch as punctuation aims, on the grammatical side at least, to make clear certain relationships between sentences and parts of sentences, the subject of punctuation is properly a corollary to that of the grammatical structure of the sentence. The chief difficulties in punctuation occur in connection with the use of the period, comma, and semicolon; the proper employment, therefore, of these points or stops will be stressed. It should be remembered that punctuation is not an exact and fixed science; although there is often a general agreement upon certain of the more fundamental usages, authorities disagree in minor practices. It is recommended, accordingly, that every writer follow some standard authority; if he does this, he will certainly not be far from right in practice, and—what is perhaps as important—his usage of punctuation marks will be consistent in all his writing.

The Period, Colon, Semicolon, and Comma

1. At the end of a complete independent predication, which is simply assertive or declarative (*i.e.*, which is not a question or an exclamation), and which is not joined to a following independent predication by a simple coördinating conjunction (*and*, *but*, *for*, *or*), use a *period*, *colon*, or *semicolon*.

(*a*) Use a colon in such cases only when the predication directly introduces an explanation, list, or quotation which immediately follows.

Right.—The apparatus should be set up as follows: First, clamp the flask in a position a few inches above the table; next, etc.

Right.—The President of the association introduced the speaker with the following words: "Ladies and gentlemen," etc.

Right.—Upon the table lay the following articles: A piece of glass tubing, a Bunsen burner, etc.

(*b*) Use a period at the end of such a predication when it is felt that the idea contained in the predication should be separated rather decidedly from the idea following, or when it is desired to emphasize it strongly.

Right.—This method of testing is based on measuring the amount of heat transferred to the cooling water from the condensed steam. It is extremely inaccurate and unreliable, and it can give but an approximate idea of the quantity of steam being condensed.

Right.—The results of the experiment are shown by the comparative curves (Fig. 8). From these curves it will be seen that the first method is productive of a much higher degree of efficiency than the second.

Right.—There is a popular notion that the presence of a small amount of lime in water used for the generation of steam is of no consequence. This I most emphatically deny.

(*c*) Use the semicolon at the end of such a predication when it is felt that the idea contained in the predication is more immediately connected with what follows than the use of the period would indicate.

Right.—The steam piping connecting the boilers and turbine must be disconnected from all other piping, and all openings must be blanked off; valves must not be relied on.

Right.—There is only one method by which such boys can be properly trained; this is the apprentice system.

Right.—Such a practice is certainly not safe; on the contrary, I believe it to be highly dangerous.

Right.—This new method of electroplating is highly efficient; therefore it deserves more widespread use.

(*d*) *The comma is an interior mark of punctuation and should not be used at the end of a complete independent predication which is not joined to a following predication by a simple conjunction.*

Wrong.—The submerging of coal will eliminate all elements which contribute toward the initial temperatures, whether or not such submerging is industrially practicable in any given case must be determined by experiment.

Right.—The submerging of coal will eliminate all elements which contribute toward the initial temperatures. Whether or not such submerging is industrially practicable in any given case must be determined by experiment.

Wrong.—Be sure in all cases to be accurate in your measurements, whatever you do, don't guess.

Right.—Be sure in all cases to be accurate in your measurements; whatever you do, don't guess.

Wrong.—It usually happens that such practices are not permitted, however, they are sometimes allowed under certain restrictions.

Right.—It usually happens that such practices are not permitted; however, they are sometimes allowed under certain restrictions.

Wrong.—"The element contained in this flask looks innocent enough," said the lecturer, "it is, nevertheless, one of the most dangerous explosives known."

Right.—"The element contained in this flask looks innocent enough," said the lecturer; "it is, nevertheless, one of the most dangerous explosives known."

2. Between coördinate clauses (*i.e.*, clauses which are the same in construction) joined by a simple conjunction, use a *comma* or *semicolon*.

(*a*) When the clauses are fairly short and simple in construction, use a comma.

Right.—The patient is turned on his face, and the bearer steps astride his body.

Right.—After the lantern had been adjusted, and the lecturer had signified his readiness to begin, the chairman stepped to the front of the platform.

(*b*) When the clauses are long and complex, or when a sharp separation is desired between them, it is better to use a semicolon.

Right.—The engineer from New York City who addressed the seniors yesterday afternoon on the subject of *Electrification of Steam Railways* was, it seems to me, not only thoroughly acquainted with his subject, but successful as well in making himself clear to an audience of inexperienced students; but the man from Boston who addressed the juniors this morning on the same subject very evidently did not have so wide an acquaintance with his subject, nor was his presentation so clear.

Right.—To be successful in one's profession is certainly much to be desired; but no one can reasonably expect that success will come without long, unremitting, heart-breaking toil.

Right.—He that is slow to anger is better than the mighty; and he that ruleth his spirit than he that taketh a city.

3. An adverb-clause which precedes its principal clause should be set off by a *comma*. When the adverb-clause follows the principal clause, no comma is ordinarily needed.

Right.—After all has been said, the cheapest motor in the long run is the one which costs least to operate.

Right.—When you are ready to leave, please turn out the light.

Right.—The man in the stern started the engine as the boat was pushed from the pier.

4. (*a*) Set off by *commas* any phrase or clause which modifies a preceding substantive, but which is felt to be *added to* the substantive rather than to be an integral part of it. Such constructions are called *non-restrictive.*

Right.—This planer, *standing in the worst possible position for the operator*, is, nevertheless, easier to operate than any other planer in the shop.

Right.—The machine at your right, *which has been in* *constant use for nearly ten years,* is about to be replaced by a more modern one.

(*b*) Do not set off by commas a phrase or clause which is felt to be an intimate part of the preceding substantive which it modifies. Such constructions are called *restrictive.*

Right.—A phrase *fitting closely to its substantive* is said to be restrictive.

Right.—A clause *which can not be easily detached from the substantive which it modifies* should not be set off by commas.

5. Use the comma regularly to set off parenthetic words and phrases, excepting where the parenthetic word or phrase is introduced so suddenly or is so distinct from the context that the dash or parenthesis marks would be better.

Right.—It is not to be supposed, of course, that so small an instrument will do all the work of a larger one.

Right.—Any such action would, however, be followed by his immediate dismissal.

6. *A mere subordinate sentence element should not be capitalized and punctuated as though it were an independent sentence.*

Wrong.—In one operation this wonderful machine stacks and binds the papers. Thus, in reality, doing the work of two machines.

Right.—In one operation this wonderful machine stacks and binds the papers, thus, in reality, doing the work of two machines.

Wrong.—In case of a wreck it is the engineer who is often to blame. Whereas the fireman seldom has any share in the accident.

Right.—In case of a wreck it is the engineer who is often to blame, whereas the fireman seldom has any share in the accident.

Wrong.—Three men operate the contrivance. One as driver and two as his assistants.

Right.—Three men operate the contrivance, one as a driver and two as his assistants.

Question Mark, Dash, Parenthesis Marks, Quotation Marks, Apostrophe, and Hyphen

7. Use the *question mark* after a direct question but not after an indirect question.

Right.—He asked me why this work had not yet been completed.

Right.—Why has this work not yet been completed?

8. Use the *dash* to indicate an abrupt break in the thought.

Right.—"Now," asked the professor, as he picked up his watch, "are there any questions which any members of the class would—"
"What time is it, professor?" interrupted a voice from the back row.

Right.—I believe that you are wrong and that—but just a minute; would you mind repeating your statement?

9. Use *parenthesis marks* to enclose parenthetic words and phrases. Do not use the marks where a pair of commas will serve.

Right.—It was just about this date (May 13, 1912) that the city began to consider the matter of a smoke ordinance.

Right.—The tungsten lamps (everybody will remember their fragility) were exceedingly difficult to handle in testing.

Right.—The price to be paid for the concrete construction work on the bridge shall not exceed eight thousand, five hundred dollars ($8,500).

10. Use *quotation marks* to enclose direct quotations but not indirect quotations. Only words actually quoted should be enclosed.

Wrong.—He said "that the failure of the bridge was due to faulty design."

Right.—"The failure of the bridge," said the lecturer, "was due to faulty design."

Wrong.—He was of the opinion, to give his exact words, "that such an error could not possibly happen again."

Right.—He is of the opinion, to give his exact words, that "such an error can not possibly happen again."

11. Use the *apostrophe* with possessives (excepting the possessive adjectives *hers*, *its*, *ours*, *yours*, and *theirs*), and to indicate the omission of a letter or of letters in a contracted word.

Right.—The fireman's shovel; the superintendents' offices; Charles's bicycle; can't, hasn't, don't, etc.

12. For the use of the *hyphen* it is difficult to give any specific rules. "The practice of lexicographers, authors, and printers is so various in this matter," says Webster's Dictionary, "that in a multitude of instances it is hypercritical or whimsical to pronounce dogmatically that either the hyphened or unhyphened form is the only correct one." To secure consistency in individual prac-

tice it is well, therefore, to adopt and follow closely some standard authority, learning to employ readily a list of words (such, for example, as *cast-iron* (adj.), *hydro-electric*, *safety valve*, *candlepower*) as they are printed in a standard dictionary or in the rules governing the printing of engineering papers adopted by a high-class technical magazine or by an engineering institute. In this way only is it possible to secure any uniformity of practice.

Good and Bad Sentence Construction

The difficulty of writing a genuinely good sentence has already been pointed out at the beginning of the chapter. Even when the writer has an acquaintance with the grammatical structure of the sentence and can make proper use of the auxiliary device of punctuation to assist in indicating to his reader the relationship of sentence elements, his sentences may still be but vague and weak carriers of his ideas. To obtain even reasonable clearness and force he must be constantly on his guard to avoid rhetorical errors, to keep from writing straggling and badly planned sentences, or sentences in which the relationship of parts can be made clear by no amount of care in punctuating. The following pages will be devoted to an explanation of some of the most frequent and insidious faults in sentence construction and the methods of avoiding and correcting them. In studying these errors and principles, the student should remember that no analysis of printed sentences, good or bad, will have much effect unless such study results in self-criticism. Every inexperienced writer should be a perpetual skeptic concerning the grammatical and rhetorical soundness of his sentences and should suspect them of containing all the mistakes in the calendar until he is convinced of their genuine clearness and force. This means a thorough familiarity with the nature of the mistakes to which he is liable and a painstaking revision of everything which he writes. At first such revision will be slow; with practice it will, however, become more rapid and more accurate. It is the aim of the following pages to give the student the necessary familiarity with some of the errors to be avoided.

The sentences used to illustrate the principles discussed were, with a few easily recognizable exceptions, taken from engineering magazines and pamphlets. Inasmuch as they embody various degrees of ineffectiveness in construction, from positive badness to mere flabbiness or weakness in emphasis, no attempt has been made to label each one with a descriptive word indicative of its structural inadequacy. When two sentences are printed side by side, the one at the left, labeled *Original*, is meant to be an illustration of the particular fault or weakness which has just been explained; that at the right, labeled *Revised*, embodies an attempt to improve the original sentence.

1. Sentence Unity

The principle of sentence unity requires that every sentence be so constructed that it is at once felt to be a unit. This means that ideas which have no relationship should not be forced into the same sentence; it means also that the tendency to write long, rambling sentences without definite plan or capacity for creating a unified impression should be avoided. To be unified a sentence need not be short. "Jesus wept," the shortest verse in the Bible, is, of course, a unit; but so also is the following beautiful sentence from Ruskin's *Stones of Venice*, planned and written with the "sentence feeling" of a genius:

"Then let us pass farther towards the north, until we see the orient colors change gradually into a vast belt of rainy green, where the pastures of Switzerland, and the poplar valleys of France, and the dark forests of the Danube and Carpathians stretch from the mouths of the Loire to those of the Volga, seen through clefts in grey swirls of rain cloud and flaky veils of the mist of the brooks, spreading low along the pasture lands; and then, farther north still, to see the earth heave into mighty masses of leaden rock and heathy moor, bordering with a broad waste of gloomy purple that belt of field and wood, and splintering into irregular and grisly islands amidst the northern seas, beaten by storm and chilled by ice-drift, and tormented by furious pulses of contending tide, until the roots of the last forests fall from among the hill ravines and the hunger of the north wind bites their peaks into barrenness; and, at last, the wall of ice, durable like iron, sets, deathlike, its white teeth against us out of the polar twilight."

This is, of course, a "literary" sentence, and perhaps for that reason it is unfair to contrast it with the following loose-jointed, rambling sentence in which no pretensions to literary quality are made; but the difference between the two is startling and instructive:

"With my aeroplane, after all my work of three years, devoted especially to improving the efficiency of the engine, which is, after all, one of the most important matters to be considered, no further experiments could be made because of the lack of funds, and so the work had to be suspended, and likewise other now very much needed experiments concerning automatic balance propulsion and so forth, can not be made for the same reason respectively because there is no experimental station in America where the inventor who has been working for some time on his device can get his invention tried out without cost to the inventor, who as a rule has not sufficient funds for that purpose and becomes, therefore, discouraged and inclined to give up all further effort, whereas a place for trying out his plans might encourage him to continue his work."

The method of correcting a sentence which lacks unity is either to reconstruct it upon some definite, orderly plan or—much oftener—to break it up into two or more sentences.

Corrected Sentences

Original

A process of "breaking down" is now necessary to reduce the mill cake to a fine meal, so that it can receive a uniform pressure, and the machine employed is fitted with a pair of gun-metal rollers, cylindrical in shape, by which the mill cakes are ground to fine particles.

Revised

A process of "breaking down" is now necessary to reduce the mill cake to a fine meal so that it can receive a uniform pressure. The machine employed to accomplish this result is fitted with a pair of gun-metal rollers, cylindrical in shape, by which the mill cakes are ground to fine particles.

Original

On this floor we also have a competent vulcanizing department under the supervision of R. M. Smith, whose father was for years in the employ of

Revised

On this floor we also have a completely equipped vulcanizing department under the supervision of Mr. R. M. Smith. Mr. Smith uses only our company, and who uses none but the best stock in the market in the production of work which is well and widely known.

the best stock in the market, and his work is well and widely known.

Original

It was a west-bound passenger train stalled at Wellington by snow-blockades that was swept to destruction at the beginning of last March together with four electric locomotives used in the Cascades tunnel, which had been recently electrified under the direction of Mr. James P. Ballentine, the well-known engineer, and a part of the town of Wellington.

Revised

Last March a west-bound passenger train, which had been stalled at Wellington by snow-blockades, four electric locomotives, which had been in use in the recently electrified Cascades tunnel, and a part of the town of Wellington itself were together swept to destruction by a snow avalanche.

2. Coördination and Subordination

An analysis of our mental processes will often show that of a group of associated ideas which crowd our minds at the same time some are relatively important and others relatively unimportant. Good sentence construction demands that whenever such closely associated ideas are expressed in the same sentence, the important thought be expressed in the principal clause and the subordinate thoughts in subordinate clauses or phrases. For example, if the two thoughts, "The fireman opened his dinner-pail," and "The boiler exploded," are to be united in one sentence, it is better to write, "Just as the fireman opened his dinner-pail—(the obviously subordinate idea expressed in a subordinate clause)—the boiler exploded"—

(the obviously main idea expressed in principal clause)—rather than "The fireman opened his dinner-pail—(subordinate idea expressed in principal clause)—just as the boiler exploded"—(the main idea expressed in a subordinate clause). In other words, the structure of the sentence should reflect accurately the relative importance of the ideas which it contains.

A tendency which should be especially guarded against is that of stringing ideas together loosely by simply adding one independent clause to another with no attempt to indicate relative importance of ideas. This fault results in a perfectly flat, monotonous, childish style, in which all ideas expressed seem of equal importance. It is illustrated in the following thoughtlessly written sentence, in which, it will be observed, there has been no attempt whatever at subordination:

"We learned that it would take some time to repair the automobile, so we walked to the nearest village, had some lunch, and returned to the scene of the accident, but the machine was still out of repair, so we tried to help the driver fix it, but our efforts were all in vain, so we sat down and waited for another car to come along."

The method of correcting sentences which have errors of excessive coördination or of incorrect coördination and subordination is so to reconstruct them that the structural importance of the ideas corresponds to their logical importance. Often the sentence can be best improved by an actual absorption of one or more of the predications as in the following sentence:

Original	*Revised*
This fact rendered the progress of the work very slow,	This fact rendered the progress of the work very slow,

and the cost of excavation ran up to an almost prohibitive figure.	and thereby increased the cost of excavation to an almost prohibitive figure.

The compactness and singleness in point of view make the corrected sentence much more effective and readable than the original one.

Mere structural subordination of the dependent idea to the principal one is usually not enough; the quality of the subrelationship should also be shown, whether temporal, causal, or what not. For example, it is better to write, "Since the pulley had a bad flaw, it gave way while the machine was in full operation," than "Being a pulley with a bad flaw, it gave way while the machine was in full operation." The participial phrase of the second sentence is quite colorless; the adverb-clause of the first sentence indicates, on the other hand, the relation of cause and result existing between the two ideas.

Careful attention to subordination and coördination results in variety and richness in style and accuracy and perspective in the expression of related ideas.

Corrected Sentences

Original	*Revised*
Experience has proved that the latter method has many advantages, the cost being here considered first.	Experience has proved that the latter method has many advantages. Of these the first which will here be considered is the cost.

Original	*Revised*
The engine was on its way to a fire when it skidded in making a turn and was toppled over.	As the engine was on its way to a fire, it skidded in making a turn and toppled over.

Original	*Revised*
The external characteristic is a clean, smooth curve rising rather rapidly at first, and then, as the field becomes saturated, it gradually droops over.	The external characteristic is a clean, smooth curve, which rises rather rapidly at first and then gradually droops over as the field becomes saturated.

Original	*Revised*
The outer casing is to be of either cast iron or steel plate with cast-iron base and top-plate, the whole being substantially and rigidly braced.	The outer casing is to be either of cast iron, or of steel plate with cast-iron base; with either construction the whole is to be substantially and rigidly braced.

3. Parallelism

In the planning of a sentence one of the most useful rhetorical devices is that known as parallelism. The principle of parallelism demands that whenever two or more ideas perform the same logical function, that fact should be shown by a similarity of structure of the different phrases or clauses which embody them. The following sentence exhibits very bad parallelism:

"Such stunts as (1) forcing a student from his room, (2) compelling him (*a*) to roll peanuts with his nose, (3) barking at the moon, and (4) proposing to coeds at Harmony Hall are not likely to result in severe bodily injury."

The parallel phrasing of this sentence indicates that (1) *forcing*, (2) *compelling*, (3) *barking*, and (4) *proposing* all have the same logical function, and that (*a*) *to roll* stands quite alone. But this is not true; the sophomores do the (1) *forcing* and the (2) *compelling*, and the fresh-men do the (3) *barking* and the (4) *proposing*, and (*a*) *to roll* is not logically isolated. Incidentally, *forcing* and *compelling* are not *stunts*. With the phrases correctly paralleled so as to show the proper logical association of ideas, the sentence will be written as follows:

"(1) Forcing a student from his room and (2) compelling him to perform such stunts as (*a*) to roll peanuts with his nose, (*b*) bark at the moon, and (*c*) propose to coeds at Harmony Hall are not likely to result in severe bodily injury."

Here the structural form shows at a glance the proper relationship between (1) *forcing* and (2) *compelling*, on the one hand, and (*a*) *to roll*, (*b*) (*to*) *bark*, and (*c*) (*to*) *propose*, on the other hand.

Bad parallelism may result from the failure to place the two members of a pair of correlative conjunctions (*not only* ...... *but also*; *either* ...... *or*; *neither* ...... *nor* *both* ...... *and*; *whether* ...... *or*; etc.) before coördinate sentence elements. The following sentence illustrates this fault:

"Before a sentence can be said to be well written, *not only* must it be correct in grammar, *but* vigorous in construction *also*."

In order that the correlatives here may precede coördinate sentence elements, this sentence must be written:

"Before a sentence can be said to be well written, it must be *not only correct* in grammar *but also vigorous* in construction."

Here the correlative conjunctions precede corresponding coördinate adjectives.

Care should be taken not to indicate a parallelism of construction where the sentence members concerned are not actually coördinate. The following sentence illustrates this fault:

"Drawing instruments must be kept (*a*) clean, (*b*) free from dust, and (*c*) must be well oiled."

Here the omission of the conjunction *and* between (*a*) and (*b*) indicates that (*a*), (*b*), and (*c*) are structurally coördinate; such is not, however, the case. This sentence should be written either:

"Drawing instruments must be kept (*a*) clean, (*b*) free from dust, and (*c*) well oiled," or,

"Drawing instruments must be kept (*a*1) clean *and* (*a*2) free from dust, and (*b*) must be well oiled."

Corrected Sentences

Original	*Revised*
It is usually the most practicable to allow the tile to be laid directly on the sand, and bend all efforts to keeping the tile clean, superfluous water drained away, and the prevention of flood water overflowing the tile.	It is usually the most practicable to allow the tile to be laid directly on the sand, and then to bend all efforts toward keeping the tile clean, superfluous water drained away, and flood water from overflowing the tile.

Original	*Revised*
Overheating of gas-engine cylinders may be due to improper flow of water through the cylinder water jacket, to the water jacket's having become coated with scale, or to have an accumulation of dirt it in.	Overheating of gas-engine cylinders may be due either to improper flow of water through the cylinder water jacket, or to an accumulation of scale or dirt in the jacket.

Original

When planning a tile system, an engineer is in danger of being misled by the appearances of the low lands as compared with the soggy, wet lands, and thorough drainage planned for the wet lands and little or none for the lands lying higher up the slope.

Revised

When planning a tile system, an engineer is in danger of being misled by the appearance of the low lands as compared with that of the soggy, wet lands, and of providing thorough drainage for the wet lands and little or none for the lands lying higher up the slope.

Original

The bearings shall permit of ready inspection, adjustments, and be accessible for repairs.

Revised

The bearings shall permit of ready inspection and adjustments, and shall be accessible for repairs.

4. Dangling Modifiers

Three types of dangling modifier will be considered: (*A*) the *dangling participial phrase;* (*B*) the *dangling gerund phrase;* and (*C*) the *dangling elliptical clause.*

(*A*) *Dangling Participial Phrase.*—A participial phrase is said to be *dangling* when the substantive—noun or pronoun—which it modifies is not clearly indicated. In the following sentence the participial phrase is *not* dangling:

"*Stepping up to the man in the checked suit, the officer* tapped him on the shoulder."

Here the phrase *stepping up to the man in the checked suit* very clearly modifies *officer;* it was he who did the *stepping up.* In the following sentence, however, the participial phrase is dangling, that is, structurally dependent upon no substantive with which it can logically be connected:

"There were plenty of woodchucks on the farm, but *not being very tame, I* never got near one."

Now certainly the writer does not mean that "I was not very tame;" and yet *I* is the only substantive expressed with which the phrase is structurally connected. What the writer meant to say is:

"There were plenty of woodchucks on the farm, but *not being very tame, they* kept away from me," or,

"There were plenty of woodchucks on the farm, but *since they were not very tame, I* never got near one."

In this case the error has led merely to an absurdity; many such misconstructions result, however, when the common-sense of the reader can not make the correction, in positive ambiguity and misunderstanding.

Dangling participial phrases need not come at the beginning of the sentence; often they occur within the sentence or at the end as in the following sentence:

"Before they began work, they oiled the engines, *followed by a tightening of all the belts.*"

The writer should have written:

"Before they began work, *they oiled* the engines *and tightened* all the belts."

Sentences containing dangling participial phrases should be corrected by expressing the idea of the phrase in a complete dependent clause or by reconstructing the principal clause so that the relationship between the phrase and the substantive modified is at once apparent.

(*B*) *Dangling Gerund Phrases.*—A gerund phrase is a phrase introduced by a verbal noun (*running, jumping, speaking*, etc.) which is the object of a preposition. Such a phrase is said to be dangling whenever the agent implied by the gerund is not immediately clear. In the following sentence the gerund phrase is *not* dangling:

"*In attempting to make the connection, he* received the full force of the current."

Here the *he*, clearly used as the subject of the main verb, is obviously the person who attempted to make the connection, and there is no possible misunderstanding. In the following sentence the gerund phrase is also *not* dangling:

"*In loading a plate-holder, great care* is necessary to keep out the dust."

Here the writer has in mind a general act; he is not thinking of any definite, active agent—therefore, there need be none expressed.

The following sentence is, on the other hand, bad: "*After pulling in the gang-plank, the propellers* of the great ship began slowly to revolve."

Did the propellers pull in the gang-plank? Certainly not, and yet that is what the writer has said. What he means is:

"*After the gang-plank had been pulled in* (or, "*After the sailors had pulled in the gang-plank*), *the propellers* of the great ship began slowly to revolve."

Sentences containing dangling gerund phrases should be corrected in a manner similar to that employed in the case of sentences containing dangling participial phrases.

(*C*) *Dangling Elliptical Clauses.*—An elliptical clause is, as the name implies, a clause from which the subject and predicate have been omitted. Unless the omitted subject of the clause is the same as the subject of the main verb of the sentence, the clause is dangling. In the following sentence the elliptical clause is *correctly* employed:

"*While experimenting in the laboratory, the chemist* discovered a new element."

Here *while experimenting* is seen at once to be an elliptical expression for *while the chemist was experimenting;* the subject which was omitted is the same as that of the main verb.

In the following sentence, however, the clause is incorrectly used:

"*When only twenty years old, his father* formed a partnership with him."

Was *his father* only twenty years old at the time of this business arrangement? Structurally *father* is the only noun in the principal clause which can be identified with the omitted subject of the verb in the elliptical clause. What the writer means is:

"*When only twenty years old, he* formed a partnership with his father," or,

"*When he was only twenty years old, his father* formed a partnership with him."

A sentence containing a dangling elliptical clause should be corrected either by supplying the omitted subject and predicate in the incomplete clause, or by so reconstructing the principal clause that the subject of the main verb is the same as the omitted subject of the elliptical clause.

Corrected Sentences

(*A*) *Dangling Participial Phrases*

Original	*Revised*
Stepping into the machine shop a gigantic crane is seen.	Stepping into the machine shop the visitor sees a gigantic crane.

Original

Here the sulphur in the gas is oxidized, thus preventing the formation of sulphuric acid, which would injure the machine.

Revised

Here the sulphur in the gas is oxidized, a change that prevents the formation of sulphuric acid, which would injure the machine.

Original

In arranging the apparatus for the experiment, I always set out on the table the flasks which I shall need followed by all the chemicals necessary.

Revised

In arranging the apparatus for the experiment, I always set out on the table first the flasks which I shall need, and then all the necessary chemicals.

Original

The mixture is lightly sprinkled with water just before the blocks are placed; making a rich mortar of the layer.

Revised

The mixture is lightly sprinkled with water just before the blocks are placed; this dampening makes a rich mortar of the layer.

(*B*) *Dangling Gerund Phrases*

Original

On making some tests with atmospheres of steam, a rise of the mercury higher than what might have been expected was noted by the experimenters.

Revised

On making some tests with atmospheres of steam, the experimenters noted a rise of the mercury higher than what might have been expected.

Original

In considering the subject of oxidation temperatures, freshly-mined coal was found almost immediately to exude

Revised

In considering the subject of oxidation temperatures, the investigators found that freshly-mined coal almost im-

hydrocarbons and to absorb oxygen.	mediately exudes hydrocarbons and absorbs oxygen.

(C) Dangling Elliptical Clauses

Original	*Revised*
While standing at the east end of the shop, a loosened bolt from a crane fell and struck him on the shoulder.	While he was standing at the east end of the shop, a loosened bolt from a crane fell and struck him on the shoulder, or, While standing at the east end of the shop, he was struck on the shoulder by a falling bolt from a crane.

Original	*Revised*
When wearing socks that had been in use the whole day, and were therefore fairly impregnated with perspiration, and wearing the boots he had also worn the whole day, and were therefore also fairly moist, a comparatively large current passed through his body.	While he was wearing socks and boots that he had had on all day and that were, therefore, fairly moist with perspiration, a comparatively large current passed through his body.

5. Weak Reference

Pronouns are, literally, words used instead of nouns. A pronoun has no meaning in itself but is understandable only when the substantive which it represents, its *antecedent*, is known. Thus, "He is here" does not convey a full meaning until we know what noun *he* stands for. It is, then, obvious that the use in a sentence of a pronoun the antecedent of which is not at once evident leads to an ambiguous, vague, and sometimes entirely incorrect understanding of the idea. With the so-called indefinite pronouns no definite antecedent is necessary; one may say "One must always keep his fountain pen well filled," because *one* here does not need to represent a definite substantive. When other pronouns are used, however, the substantive to which they refer must be unmistakably clear. When it is not, the reference of the pronoun is said to be *weak.*

To correct weak reference in a sentence it is necessary, of course, either to employ a noun in place of the meaningless pronoun, or so to reconstruct the sentence as to make the antecedent of the pronoun unmistakable. It is well usually to have the pronoun as near to the antecedent as possible; especial care is required to prevent the intrusion between pronoun and antecedent of another noun to which the pronoun might seem to refer. Occasionally the most satisfactory correction can be secured from an entire replanning of the sentence.

Corrected Sentences

Original	*Revised*
The inexperienced foreman had the work of digging the guy hole which resulted in being too near the post for the strain guy.	The work of digging the guy hole was assigned to the foreman who was inexperienced; as a result the hole was too near the post for the strain guy.
Original	*Revised*
A fireman should never sleep while on duty; that is highly dangerous.	A fireman should never sleep while on duty; such carelessness is highly dangerous.

Original	*Revised*
A bolt and nut may be held in the end of a turning crank or shafting by the following method, which seldom fails, even though it is inclined to work loose.	The following method seldom fails to hold a bolt and nut in the end of a turning crank or shafting even when the nut has a tendency to work loose.

Original	*Revised*
A common trouble between engineers and their clients is that they do not have the proper respect for them.	A common trouble between engineers and their clients is that the engineers do not have proper respect for the clients.

6. Order of Parts

In the section of this chapter which deals with the grammatical structure of the sentence it is shown that many sentences—all, in fact, but the very shortest and simplest—contain modifying phrases and clauses. Now it is obvious that whenever in a sentence it is difficult to understand at once just what noun or verb a given adjective or adverb or adjective- or adverb-phrase or clause modifies, the result is likely to be a confused and blurred conception of the idea. Such confusion often arises from a loose arrangement of the elements of the sentence, from a lack of care in putting modifiers next to the words which they modify. This lack of care is evident in the following sentence:

"The smooth vacuum cups wash anything from the most delicate and sheerest laces to rag-rugs, heavy bedding, or blankets *without tearing*."

Here the phrase *without tearing* would seem from its position to be an adjective-phrase modifying the noun *blankets;* it is, of course, an adverb-phrase modifying the verb *wash.* The sentence should read:

"The smooth vacuum cups wash *without tearing*, anything from the most delicate and sheerest laces to rag-rugs, heavy bedding, or blankets."

The comma has been used after *tearing* to prevent mistaken junction of *tearing* and *anything.*

The following sentence is also ineffective because of a bad arrangement of parts:

"A perfect bond must at all points be secured with the underlying concrete."

This should read:

"A perfect bond with the underlying concrete must be secured at all points."

A very frequent displacement in sentence construction is that of single adverbs, especially of the adverb *only.* An adverb should be so placed that the verb, adjective, or other adverb which it modifies is unmistakably evident. One should not write, "I *only earn* fifteen dollars a week," as though the writer means to emphasize the fact that he does not *spend* or *save* that amount, when he really means, "I earn *only fifteen* dollars a week." The adverb should be so placed that it is seen to modify not the verb *earn*, but the adjective *fifteen.*

Corrected Sentences

Original	*Revised*
Another perforated ring showers water over the head which is made of metal.	Another perforated ring, which is made of metal, showers water over the head.

Original	*Revised*
A water seam was struck about four feet below the rock surface which proved troublesome.	A water seam which proved troublesome was struck about four feet below the rock surface.
Original	*Revised*
It is the writer's observation that dry rot, being a fungus growth, will only attack structural timbers when a certain degree of humidity is present.	It is the writer's observation that dry rot, being a fungus growth, will attack structural timbers only when a certain degree of humidity is present.
Original	*Revised*
This form of combustion chamber is not possible in the construction of the poppet valve motors because of the presence of pockets in the cylinder walls which have a small volume and a very large heating surface.	This form of combustion chamber is not possible in the construction of the poppet valve motors because of the presence in the cylinder walls of pockets which have a small volume and a very large heating surface.

7. Logical Agreement

Many sentences are bad because of illogical agreement between parts. In general, this fault usually results from the writer's failing to say just what he meant to say. Sometimes the lack of logic is apparent in the circumstance that an expressed or implied comparison is made up of elements which can not be compared. Occasionally, too, the writer is guilty of saying that something *is* something else which it can not possibly be. An excellent example of an illogical statement follows:

"There is *quite a gap between these boys*, usually office boys and messengers, *and the positions* as shippers, etc., and to get them there I propose the apprentice system."

Now how can a gap exist between *boys* and *positions?* There can be a gap between messenger boys and shippers, or between the positions which the boys hold and those which the shippers hold, but the writer has not said so. The sentence might be rewritten so as to read:

"There is quite *a gap between the places* held by these boys, usually office boys and messengers, *and the positions* held by shippers and employees of similar rank; and to get the boys over the gap I propose the apprentice system."

To correct illogical statements it is necessary first to perceive clearly at what point in the sentence the bad logic exists; and then so to reconstruct the entire sentence that it is the exact and logical expression of the idea which the writer wishes to convey.

Corrected Sentences

Original	*Revised*
This cost is less than many miles of macadam road.	This cost is less than that of many miles of macadam road.
Original	*Revised*
A test quite as important as the one just mentioned is the flashing point.	A test quite as important as the one just mentioned is that to determine the flashing point.
Original	*Revised*
The test for ash consists of burning a portion of the sample and weighing the	The test for ash consists of burning a portion of the sample, weighing the residue,

residue, and the per cent. is found in a similar manner to the other tests.

and determining in a manner similar to that employed in the other tests what percentage of the whole this residue forms.

8. Incomplete Statement

Bad sentences often result from the attempt of the writer to express his ideas more concisely by omitting necessary words and phrases. This practice of making the reader supply the omitted words often results absurdly, as in the following notice impaled recently on a hook in the coat-room of a college recitation hall:

"Will the student who removed my coat from this hook by mistake last Friday morning kindly return and hang on the hook?"

Now however perturbed in spirit the writer of this notice may have been, he certainly did not desire capital punishment for the student who had carelessly carried off his coat. What he quite obviously meant to write is:

"Will the student who removed my coat from this hook by mistake last Friday morning please return the coat to the hook?"

Incorrect omissions of auxiliary verbs in compound sentences are very frequent. The following sentence illustrates such an omission:

"The door is then bolted and the windows securely locked."

Here the auxiliary verb *is* of the first clause is incorrectly allowed also to serve with a noun in the *plural number* in the second clause. The sentence should read:

"The door is then bolted, and the windows *are* securely locked."

Corrected Sentences

Original	*Revised*
I have tried dipping in sulphuric acid but still have some spots.	Although I have tried to clean (the rusty instruments) by dipping them in sulphuric acid, I have not been able even by this method to remove all the spots.
Original	*Revised*
While storage bins are built of concrete and steel, the prevailing practice is to build them of timber.	Although storage bins are occasionally built of concrete and steel, the prevailing practice is to build them of timber.
Original	*Revised*
The working man careful in these operations without the use of a file the teeth will work fairly well.	If the working man is careful in these operations, the teeth will cut fairly well even if they are not filed.
Original	*Revised*
It is, as it were, but a fortnight since the idea of an aeronaut flying head down, looping the loop, and even defying the skill of the birds, who have been supreme in the air all the past centuries.	It is, as it were, but a fortnight since the idea originated of an aeronaut flying head down, looping the loop, and even defying the skill of the birds, who have been supreme in the air all the past centuries. (At best this is a flabby sentence; the thought is conventional, and the phrases are inflated.)

Original	*Revised*
This boiler is in need of repair, for the lining is badly scaled and the bolts loose.	This boiler is in need of repair, for the lining is badly scaled, and the bolts are loose.

9. Weak Emphasis

It is not enough that a sentence be clear; the ideas which it contains must be properly emphasized—that is, the unimportant ideas must be made relatively inconspicuous, and the important ideas must be stressed. A part of this light and shadow in a sentence will result from a careful attention to proper coördination and subordination of the associated ideas (see page 101); but in addition it is desirable so to arrange the parts of the sentence that the important ideas come in the important positions. These are the *beginning*, since words at the beginning strike the attention of the reader first after the break of the full period stop, and the *end*, since words at the end are ordinarily at the climax of the sentence and stand out also because of their position just before the full period stop. In a lower degree the positions just after and just before the semicolon are also emphatic.

In general, then, the principle of good sentence emphasis demands that the flat, obvious, "filler" words of the sentence be tucked away inconspicuously within the sentence, but that the words which express the real thought and force of the sentence idea be emphasized by a conspicuous position either at the beginning or at the end. This has not been done in the following sentence:

"The columns supporting the outboard end of the generator are entirely independent of the rest of the foundation, because of its being impossible to carry the foundation over the discharge-tunnel structure."

Here the leading idea is contained in the words *entirely independent of the rest of the foundation.* This idea has, however, been smothered up within the sentence, whereas a subordinate idea has been allowed to usurp the emphatic position at the end. The sentence should be written:

"Since it was found impossible to carry the foundation over the discharge-tunnel structure, it was necessary to make the columns supporting the outboard end of the generator *entirely independent of the rest of the structure.*"

In the following two sentences, in which the necessity for good emphasis is, because of the contrast involved, very great, the emphasis is, nevertheless, exceedingly weak. In the column at the right an attempt has been made to improve the sentences.

Original	*Revised*
In the steam plants, never more than fifteen per cent. of the coal is transformed into mechanical work. On the other hand, in the producer-gas plants, never less than fifteen per cent. of the energy of the coal is transformed into work.	In steam plants the amount of energy in the coal which is transformed into mechanical work is never *more* than fifteen per cent. In producer-gas plants, on the other hand, the amount of energy in the coal which is transformed into mechanical work is never *less* than fifteen per cent.

Sentences in which the emphasis is weak can be improved by such a rearrangement of parts as will bring out the important ideas and throw into the background the unimportant and obvious ideas. Usually this will mean also a more logical arrangement of parts; for example, the cause should usually precede the result or effect, and a detail occurring at one time should usually precede a detail occurring at a later time. The matter of proper sentence perspective may seem in the case of any given sentence to be relatively unimportant; care in such details produces, however, writing which is clear and vigorous; inattention to these matters leads to writing which is merely passable.

Corrected Sentences

Original	*Revised*
The culvert saved the apparatus from going over a retaining wall and taking an eight-foot drop, however.	The culvert, however, saved the apparatus from going over a retaining wall and taking an eight-foot drop.

Original	*Revised*
There will be a lecture on *The Cause of Storms* on Thursday, April 26, at 8 P.M. in the Chemistry Auditorium by Mr. John J. Patron of the U. S. Weather Bureau.	*The Cause of Storms* will be the subject of a lecture by Mr. John J. Patron of the U. S. Weather Bureau in the Chemistry Auditorium on Thursday, April 26, at 8 P.M.

Original	*Revised*
The pat thus made seemed to harden, but disintegration immediately took place when it was immersed in water.	The pat thus made seemed to harden, but, when it was immersed in water, it immediately disintegrated.

Original	*Revised*
On the first floor of the building the offices of the	On the first floor of the building are the offices of the

directors and the correspondence filing rooms are to be seen. In the basement the storing, packing, and shipping rooms, connected to the driveway by an incline, are to be found.

directors, and, to the rear, the correspondence filing rooms. In the basement, which is connected to the driveway by an incline, are the storing, packing, and shipping rooms.

Original

Automatic inlet valves give good results in small engines, while never as efficient as the mechanically operated types.

Revised

Automatic inlet valves, although never as efficient as the mechanically operated types, nevertheless give very good results in small engines.

Defective and Weak Sentences for Revision

The following unclassified sentences were taken from technical magazines and student themes. In correcting each sentence, determine first by a careful analysis wherein the error or weakness in construction lies; then rewrite the sentence, making a complete and smooth revision. Where it is impossible to understand the original idea, so reconstruct the sentence as to express clearly the thought which it seems probable the writer meant to convey. It is often unfair to a sentence to criticize it out of its context. An effort has been made, however, to include in this exercise no sentences which can not be individually improved without reference to the context. Many are merely weak, flabby, unemphatic, crude, or otherwise ineffective; such sentences should in the process of revision be made more vigorous and clean-cut. The aim of the exercise is to cultivate in the student a feeling for good sentence construction and a standard of judgment and taste which will result in increase in his power to construct good sentences easily.

1. The viscosity is determined by comparing the time required for a given amount of oil to flow through a certain orifice at a given temperature to the time required for the same amount of water under the same conditions.

2. Before purchasing this pump, many different devices for raising water were considered.

3. Another precaution necessary is to see that the concrete forms a solid and compact mass, especially around the steel, this being brought about by the tamping and puddling of the mixture as it is being poured.

4. First of all it might be well to state that all weighings are made to four decimal places, as the results should be accurate to the tenth of a per cent.

5. The cylindrical valves are entirely operated by water pressure.

6. On entering the soldering machine, laborers placed covers on the cans.

7. As soon as the operator perceives this, he closes the globe valve *F*, then the valve *D* is closed, and the valve *C* is partially opened.

8. I will not have men who have not had a college training at the head of any department.

9. Combustion engines, or gas engines as they are generally known, are to-day built in various sizes and kinds. The size of the engine depending on the size and number of the cylinders.

10. At each suction stroke of the engine gasoline will be drawn into the vaporizing chamber due to the slight

vacuum created there, and it will be absorbed by the air which is being drawn in through another opening.

11. In many other industries, such as the whiskey and alcohol, distillation plays an important rôle in the manufacture of their products.

12. Thousands of miles of electric railways have been built, many of them performing service comparable to steam railways both with motor cars and locomotives, but up to date only a few thousand miles of steam railway trackage has been equipped for electrical operation.

13. Its widespread use not only for automobiles, water and air-craft as well as for stationary uses illustrates its wide application.

14. Lost: an analysis on the cinder path.

15. Three men were trying to pull an ice-boat out of the water that had broken through the ice.

16. There are at the present time two large engines as can be seen on the sketch.

17. The conditions under which the determination is made are arbitrarily fixed so that the results obtained by different chemists may be comparable and form a basis for the comparison of the coals analyzed.

18. When heating the wet powder over a mine lamp, it exploded violently.

19. My father was of Scotch descent while my mother was of German descent.

20. The main building of this plant is of red brick. being about 120 feet square, 60 feet high, with only a few windows in the whole building.

21. Such men usually have no knowledge of the gas business or any other public service business and in most cases never acquire any substantial knowledge of the same and are induced to form the company and engage

in the business by some construction contractor, who himself sometimes, is deficient in knowledge, has never successfully operated a plant, and if so inclined he could not intelligently elucidate the real needs and requirements of a new gas plant and the organization necessary to bring success.

22. The Wisconsin statutes covering food products are known to be the most stringent of the States.

23. The way to avoid all these errors is to be neat and orderly in all computations even though at first thought it seems to require more time whereas in reality the converse is true.

24. Fig. 4 illustrates a receiver the bottom of which is set lower than the pump cylinders, but the water level is above them because the receiver is large in proportion to the pump.

25. No failure of the main motor fields have occurred; the armature windings have merely required repairs from time to time.

26. The accompanying sketch shows how a small machine is built from a shaft hanger and a few easily made forgings, which does not require much time to construct and is efficient when put in operation.

27. Nor will students be required to study any foreign language during their college career by the new bill.

28. Direct current has an advantage over alternating current in the charging of storage batteries, but due to the fact that storage batteries usually form only a small part of the load of a generating station, and when it is considered that mercury rectifiers are a very convenient means of converting a.c. into d.c., it will be understood that this advantage is a very slight one.

29. The heating plants are usually run by corporations having other large industries under their control which use large quantities of steam, such as electric power plants.

30. The small investment will be nothing when prorated over five years, compared with the benefit of having all water and gas cuts promptly repaired.

31. Instead of pitch grouting, it is common practice in Paris to flush the surface with cement grout.

32. There are two divisions in the open-hearth process. One basic and the other acid.

33. At the end of five or six hours the silicon and manganese have been burned out and the carbon much reduced.

34. The method of operation is for the piston to suck in the charge of air through the main valve, and this, during compression, is forced right back into the vaporizer, mingling with the gas generated by contact of the injected oil with the hot walls of the vaporizer, which being at a sufficiently high temperature, as soon as an explosive mixture is formed, ignites the charge.

35. It is a question that I have threshed out with myself and always arriving at the same conclusion.

36. It has been previously stated that one of the advantages of the modern interurban system in competition with steam roads is its ability to transport the passenger to more nearly the exact point in a terminal city to which he wishes to go and often gives him transfer privileges upon the local railway system if necessary.

37. Before starting to tamp the mixture more water was mixed in, using as much as the soil would hold.

38. In the Bessemer process the charge is molten pig iron, which contains some five per cent. of carbon and

considerable manganese and silicon, but phosphorus and sulphur must be as low as possible, for none is removed here.

39. The University Heating Plant is located on University Avenue on the opposite side of the street and one square west of the Chemistry Building. The building of the Heating Plant, which is rectangular in shape, is built of light pressed brick. A large black smoke-stack towers about seventy-five feet above it, the smoke from which is gradually darkening the red tile roof of the plant.

40. Nearly all the tungsten is produced from fields in Colorado and California, and in the former state the Boulder field, which is the greatest producer, is situated.

41. Her lines are free and easy running in an unbroken sweep from stem to stern showing great strength and sea-going qualities.

42. This company lays most of its own blocks, and a large proportion of its contracts are in London; these blocks are delivered to the street in wagons.

43. I gave the monkey in charge to one of the slaves to feed and nurse it, being a very tender sort of animal.

44. For this purpose large enclosed tanks are used and they are heated by steam coils arranged along the inside of the tank.

45. With the new system the necessity of carrying a lantern to the barn and the worry of setting it in some place to give the best light and where it will still be secure from falling, is all eliminated.

46. Four pulleys guide a small endless belt around the disc and touching the rollers thereon at two different points diametrically opposite and on the same axis of the frame.

47. The salesman's convincing, yet not overbearing

manner, together with an accumulated knowledge of the various types of human nature, will enable him to convince the customer indirectly the type of shoe he is interested in.

48. The cost of gas for each filling of a large balloon is alone enough to place it out of the question for performing commercial travel at reasonable cost.

49. Tests made recently in England with the Gambrel vacuum brake have shown it to be highly effective on light automobiles, the only essential to their use being the running of the engine.

50. The cut is fifty feet deep, three city blocks in length, and is made in rock and earth.

51. The front spring of an automobile broke while on a trip and it was repaired in the manner shown in the sketch.

52. This point can be overcome almost entirely by drawing the temper with a torch, a pair of hot tongs, or by dipping the shank into hot lead and letting the blue just begin to run into the thread.

53. This is desired, for, upon closing the switch, the passage of the electric current through the solution causes silver to plate out upon the metal.

54. These processes of course, vary both in variety and in number according to the article and the use it is intended.

55. A glass tank contains the electrolyte and has two bus-bars fixed to its top.

56. The above theorem only relates to the velocity of the particles.

57. We frequently receive letters from users who have driven this car up hills that no other automobile of any kind has ever been able to negotiate; through mud that

has stalled horses and wagons; have pulled cars of 35 and 40 horsepower and their passengers up grades that stalled these cars; driven through snowdrifts, up steep inclines covered with ice; and in places where a horse and buggy could not possibly go.

58. It is seen that the heating of the water will be accelerated due to the large heating surface of the tubes within the boiler.

59. By wireless from Arlington is the best way to get the correct time, because it is a government station and also wireless waves travel about three thousand miles a second while in line telegraphy there is a large amount of resistance and thus the time is not as accurate.

60. This system is probably better known and higher rated than any known system.

61. The results, which were satisfactory, showed that sawdust is an excellent extinguishing agent for certain volatile liquids, especially those of a viscous nature, and were presented in a paper read at the recent annual meeting of the American Society of Mechanical Engineers by Edgar R. Roberts, Chicago, who is identified with the inspection department.

62. In one case there is a report on a No. 300 crucible which ran forty heats on manganese bronze, and there are dozens of cases as high as thirty-eight and forty heats on No. 100's, melting car-box metal.

63. The effect of carelessness was well illustrated on a sheet asphalt pavement in a Western city.

64. The striking of a medal is entirely mechanical and is obtained by either hydraulic pressure, or a screw press.

65. Pieces of wood were planed out and held in the

chuck of the lathe and the tool run on the wood while it was turning.

66. One trip in particular, between Toledo and Detroit, which trip was made during a continuous rain storm, in a prominent make of car belonging to the writer

67. The power is controlled by a switch on the handle by the operator.

68. These contacts, usually about eight in number, are made of brass buttons one-half inch in diameter and one-eighth inch thick having a stud going through the slate, and being connected to the resistance element on the rear.

69. The lever is of cast iron having mounted on its under side a copper riding contact riding over the contacts as the lever is moved to the right in starting the motor.

70. Many combinations in electric plants using boiler compounds having soda ash as a base have noticed a tendency to discolor the distilled water condensate to a reddish hue, resulting in making "red" ice.

71. Theoretically, therefore, but probably with longer bearings than are now used, this should produce the best results, for automobile work, if properly applied.

72. In seeking an explanation of the rapid burning of fuse in a number of experiments, several samples of the fuse were especially treated by the experimenters so as to remove all the tar and asphalt in them.

73. The result was that it was impossible to locate anything—thousands of dollars worth of tools were constantly lost—the duplicating of tools representing a large investment, and the tools were often not in proper condition.

74. Their duty is to pick out any discolored peas, for

these spoil the looks of a can, and at present no means of removing them has been discovered.

75. A device has been devised by Cooper and Cooper, N. Y., which furnishes a simple means of removing the limitations.

76. There remains the argument against it of requiring considerable labor, necessitating the use of tongs to turn up the edges, also the need of forming edge strips in the shop when for strips of the shape shown, a brake would be necessary for the forming of them.

77. Few people are aware that out on the northwest side is the largest motion picture factory in the world and to it it will pay a visit.

78. While a shot shell does not in the true sense of the term contribute to the highest welfare of the world, nevertheless the processes employed by the Diamond Cartridge Co., Quebec, Canada, in its manufacture are fairly interesting.

79. It seems, therefore, preferable to lay the responsibility of the repair upon the shop foreman in the first instance.

80. In reporting on this engine there are two things to be considered; one is the condition of the stoking machinery, the other being the condition of the boilers.

81. It is arranged in such a manner that eight men can work at the lathes, while others can cut wood preparatory to being turned.

82. If he can't set his derrick on the roof and must leave it on the ground, if the derrick is short he will have to hitch to the stacks below the centre and he must in this case tie a weight to the bottom of the stack or hold it with ropes to keep it upright, then when the stack

is raised, have his men take the guy wires and pull it up straight to be let down on the boiler.

83. Essentially the process consists of three steps, drying, mixing, and pulverizing the raw material; burning the pulverized material to form clinkers, and pulverizing the clinkers.

84. T. B. calls attention to a defect of the gear hobbing machine that I have not seen in print.

85. Limestone is almost universally employed and its value as a flux depends upon its freedom from impurities.

86. When a horse pulls a cart, then, if the cart pulls back on the horse an equal amount (as the law states) why is it that they generally move forward?

87. An engineer who has been trained for electrical work may be called upon at any time to erect a transmission line, lay out plans for a dynamo room, or one of many possibilities that the person hiring him could very well expect him to accomplish.

88. One man may be very good in subjects dealing with chemistry; another may lean toward civil engineering work and the construction of large structures; still another may not care for either of the above-mentioned lines of work but who would take great interest in electrical or mechanical subjects.

89. The construction of the manhole, the bumping of the head, and the method in which the manhole is made steam-tight, were noted. Next the dry pipe, the baffle plates, and the feed-water pipe were observed. A large amount of scale, pitting, and corrosion on the surface of the drum was found.

90. The amount of water and the depth from which it must be lifted are the chief considerations in choosing a pumping system.

91. They have now been in use some time satisfactorily and we drill 5 or 6 holes without sharpening and the diameter shows no decrease from the original length.

92. This has been accomplished by several patternmakers through the use of a jig for forming the teeth, making them of small blocks and gluing them to the gear blank.

93. He was only speaking of the merits of the thing and he thought it was a good thing.

94. The ordinary mower is used, but instead of leaving the hay scattered on the field to be raked into cocks, it is placed in long rows or windrows by an attachment called the buncher.

95. It is circular in shape being about four inches in diameter and about three-quarters of a full circle in length and having one end of the tube closed.

96. The spacing is largely done by guess, and the result is usually a kink on the first hot day, necessitating the replacing of the damaged rails.

97. This sewer was oval-shaped, its vertical diameter being six feet and its horizontal four feet.

98. The sheeting consisted of eight-inch planks placed tightly together in a vertical position against the sides of the trench, stringers, and braces.

99. Smoke is an indication of inefficiency and waste, and is not, as is the popular belief, an indication of prosperity.

100. Second, the correct oil must be used for a specified kind of work; as for example, animal and vegetable oils, while good for low speeds, could not be used on steam turbines as high speed causes foaming and a tendency to decompose the metals.

101. A hollow steel casting known as the water leg or

saddle is riveted to the shell over each orifice, these castings having a width equal to about three-fourths of the diameter of the boiler shell, a height of about eighteen inches, a width of six inches, and having a thickness of metal about one inch.

102. This mammoth device consists of a great steel beam, technically known as a bascule arm, unevenly but decidedly balanced on the top of a tall tower and swinging into the air to a height of 260 feet a double-decked cage freely suspended from its longer arm containing as many as 114 passengers at a single trip.

103. At the rear, like a scorpion, are set the rake teeth, which are curved and bolted to a triangular frame.

104. In it are discussed the advantages of using fly-wheel equalizers in certain cases, as compared with two other methods which are mentioned but not described in detail.

105. Considering the most common type it consists of a metal body either brass or malleable iron depending upon the conditions of operation, which is moulded into a spherical shape there being elongations on the three rectangular coördinates of a plane through the center, in order that the valve may be connected to the pipe by the two directly opposite and to hold the stem and gasket for the raising and lowering of the gate.

106. The writer is indebted to S. M. Jones, Mech. Supt., for the foregoing details, who not only directed the work, but lived on the job until all danger of a possible shutdown had been avoided.

107. There is a favorite line of steamboats making this trip which are favorites for those who do not own motor-boats.

108. The system and its various parts are fully de-

scribed and thus make the article economical for the reader.

109. This is a large tower about eighty feet high and has a maximum diameter of twenty feet.

110. As the water in the receiving tank lifts a float ball, a valve is operated in the governor chamber, which permits the water to be drawn from the receiving tank through the governor until a certain predetermined level has been reached, when the valve closes, which operation takes place before the air can be drawn in from the pump cylinder.

111. Under one side of the foundation the soil had settled due to leakage from a water pipe near the foot of the foundation whose existence had been forgotten.

112. We now have both types side by side, and when showing visitors around, which shall I refer to as the standard tool, as it was claimed for both that each represented the last word in grinders?

113. It was, of course, desirable to utilize as much as possible the natural pressure for all domestic service.

114. It is always a hard matter to get supplies into a mountain country, so that equipment has to be of light weight, such as picks, shovels, mattocks and wheelbarrows, drill steel and dynamite.

115. A similar error is introduced if an attempt is made to connect the pressure terminals on the line side of the current coils the applied pressure will be too large by the line drop between these points and the load, again making the readings too large.

116. My information is presumably correct, as we here are comparatively near neighbors to Montana, which State adjoins our own although the university at Missoula is actually about one thousand miles from my location,

117. Another very important feature of this shell bushing is that it can be renewed when worn out much cheaper than the whole spindle.

118. I was told when I took charge that the engine was much overloaded and that it had a very bad pound but that I was not to let that bother me as there had been two men from the factory trying to locate the cause but had gone away in disgust.

119. The motor starts as a repulsion type and automatically changes its connections to become of the induction type when the motor reaches a certain percentage of speed.

120. Therefore, when these questions come before us I can view them, not only from the position of the manufacturer, not only as they apply to the Association or its activity, but I endeavor to place myself back again to the time when I was an apprentice and consider matters from his point of view.

121. During recent years a large number of drainage districts have been organized in the Mississippi River valley, in which pumping is required.

122. It is utilized to locate all cable conductor troubles except opens and will locate dead shorts, or faults with a very high resistance and can be used by linemen who have a fair knowledge of electrical conditions.

123. I presume he refers to the use of return sand cones, but, as stated above, the use of these cones only involves the loss of about 2 ft. of head on 85 per cent. of the total pulp.

124. "It was framed up," declared a beautiful young woman who said she was Mrs. Annette Dryden Steinway, central figure in the fraudulent passport scandal, after being arrested to-day on charge of assaulting Mr.

Katzer, a reporter for an Italian newspaper, in hotel Marlborough early to-day.

125. To secure the special advantages which electric service may render possible, what modifications in his processes and equipments will do this is the real problem before the manufacturer.

126. Due to the intermittent operation, satisfactory operating data is not available.

127. In designing the motors we have kept them up-to-date in every respect and have added many special features such as, the patent of the gas-tight bearings, which is really considered to be the most valuable invention of its kind on two-cycle motors of the age, waterproof and spark-proof commutator which is the most simple commutator that can possibly be manufactured and will give much better and surer service than the gear-driven elevated timer, with its complicated springs and numerous small parts, the circuit-breaker or timing lever for reversing, with which you can reverse the engine, and really a boat can be handled with the Pearl-edge motors both reversing and forward practically as well as those equipped with reverse gears, etc.

128. It is predicted that more men will be employed in the Iron River district in the coming season than has been recorded in any former years.

129. After serving his time in the shop, learning the use of the various tools and how to use them, he will know what he is going for.

130. Such things as letting the lights burn all day or a shop too hot or too cold must be watched.

131. The illustration shows a dirt train being dumped on the first lift, a working trestle being erected close to the main trestle.

132. On this they experimented by hauling boulders from the size of 24 in. in diameter to as large as they could handle and placed them to make a firm foundation, then put stone on the top of them, which made a good road.

133. The appliances were not adapted to precise work but the result is not very far wrong in my opinion.

134. In three years one particular cover under my charge was lifted twenty times and the joint was perfectly good still.

135. Quite a number of visitors did come long distances to see this 250-hp. machine, and some comments were made that this was probably the upper limit in size that would ever be made.

136. Between the stampings, on ridges made in the metal, the trolleys supporting the door ride.

137. A five-ton truck, taking as many as seven cars at one time, hauled them about sharp curves over half a mile of private tracks without difficulty.

138. The steel frame is built up into an extremely rigid unit, with scientific distribution of metal, using an average of from six to eight cross-channel reinforcements, integrally gusseted, completing a rigid foundation of extreme strength, particularly adapted to the use of solid rubber tires.

139. It is announced that machinery and parts of same may be cleaned quite as satisfactorily and perhaps cheaper than by the old method.

140. Pieces of timber running across the truck are grooved to fit the bars and holding the bars apart, so that the workmen can get his hands under them or pass a leather loop around them to lift with a hoist.

141. When a watch is laid on a table and one putting

one's ear on the table a few feet from the watch, the sound of the watch running can be heard.

142. Sediment in the steam is also detrimental to turbines because of the greatly increased erosion of the blades, and in some cases clogging them.

143. Millwrights have a hard time to level up shafting after it has been in use for some time, due to the sagging of the overhead joist.

144. Water is pumped into the pit by a 4-in. centrifugal pump, taking the water from the power house supply well and the water enters the pit at the ground level.

145. The base of the lamp contains a dry battery, the connections of which, running upward through the body of the lamp, and raising the handle, forms a contact with the base of the burner, contact being broken when the handle is released.

146. For two-story dwellings one or more inside cold-air ducts are used and one cold-air duct from outside and many cases only one of the two inside cold-air ducts are supplied, but the outside cold-air duct in connection with the inside air duct makes an ideal system.

147. This being due, in the majority of cases, to turbines recently proved to be extremely wasteful and inefficient but once thought to be economical in the use of water.

148. The American method is preferable where the depth of the rock is greater than two feet in depth.

149. There are few more exasperating things than locking something securely and then not to be able to find the key.

150. When speaking on this phase of the subject, three illustrations were shown by me to prove the points which I tried to make.

PART II

TYPES OF TECHNICAL EXPOSITION

[illegible]

CHAPTER VI

TECHNICAL DESCRIPTION

Introduction to Types of Technical Exposition

It is the aim of Part I of this book to set forth some of the general principles of expository writing, the principles governing the planning of the whole composition, the organization of the paragraph, and the construction of the sentence. It is the aim of Part II to explain and illustrate some of the more specific principles which govern the composition of the types of exposition with which engineers are most concerned, technical descriptions, expositions of processes, expositions of ideas, reports, and business letters. The suggestions for effective writing which are given here are not to be understood as representing a body of formulæ universally applicable; they are designed to serve only as general guides, for each technical exposition presents to a certain extent its own compositional problems, which must be studied and solved independently. Content, plan, emphasis, and even details of construction are to be determined by the object of the exposition and by the person or persons to whom it is addressed or for whom it is designed. Any set of specific principles, therefore, should be used as a general guide,—not slavishly.

It is not, moreover, to be supposed that in actual practice the divisions between technical description, exposition of processes, and exposition of ideas are as distinct as the treatment of the three types in different chapters here would indicate. As a matter of fact, most expositions of processes contain descriptive material, and expositions of ideas may contain both descriptions and expositions of processes. But because of the differences in content and in the writer's specific aim, it is convenient for purposes of explanation to consider the types separately. In practice the principles governing each type may be employed whether the type stands alone or in combination with other types.

The *Student Themes* following the explanation of the principles are designed for class analysis and discussion. They are not offered as models, but represent work of all grades from bad themes to those which are fairly good. They have not been arranged in order of merit. As they are meant only to illustrate the correct or incorrect application of the principles set forth in the chapter of which they are a part, all minor errors of spelling, punctuation, and sentence construction have been corrected. Excepting for their mechanical correctness they may be taken as fairly representative of student writing. It is not expected, however, that they will displace themes written by members of the class, which will, naturally, be fresher in interest. Wherever possible, such representative themes should be multigraphed and distributed for class comment.

The *Specimen Expositions* which follow the student themes have been selected from the point of view of their suitability for class study; most of them have, in fact, been submitted to the test of actual class-room use. To meet the needs of such use there have been certain necessary limitations in selection.

In the first place, all articles highly technical or otherwise difficult to understand have been excluded. It is expected that the specimens will be analyzed by undergraduates in all branches of engineering and often, too, under the direction of teachers who are not themselves graduates of engineering colleges. A highly technical article, filled with mathematical demonstrations and difficult scientific explanations would demand for its mere understanding much time which should be given to its rhetorical study, while it might not, at the same time, illustrate expository principles any better than a much simpler article. Although the application of this principle has led to the inclusion of a few "popular science" articles, it should be observed that very many of the authors represented in the selection are prominent scientists and engineers writing for technical audiences.

Another principle of selection followed was to reprint only articles which possess some *body*, which provide, that is, sufficient material for a class exercise of at least one period in length. Although two or three short selections have been included, for the specific reasons indicated in the notes preceding them, the making of a mere exhibit of short articles from the technical journals has been avoided. In carrying out this principle, moreover, the selections have with one exception been reproduced *in toto* as they originally appeared; to cut down an article by omitting parts which the author, for good reasons, included, decreases its value for the purposes of rhetorical analysis.

Finally, the articles have not been selected primarily for their content. An attempt has been made to secure some variety in the subject-matter, but there has been no effort to include articles representing all branches of engineering or all possible varieties of exposition. The manner of presentation was regarded as being of more importance for purposes of study in a class in English composition than the subject-matter. In a study of the specimens it is important that this point of view be maintained lest the attention of the class be diverted to the content and away from the compositional aspects. It is necessary, of course, that the ideas expressed be understood; without such understanding rhetorical analysis would be impossible. But class time should be given to a consideration of the manner in which these ideas are presented rather than of the ideas themselves; the class, in other words, is a class in English composition, not in engineering.

Not all of the specimens are *models*, in the narrow sense of the word. Although they are expected to illustrate the principles explained in the text, several are capable of improvement in the larger matters of whole composition and paragraph, and many of the sentences are far from impeccable. A thorough study will, therefore, involve a consideration of the ways in which the specimen being analyzed can be improved.

The brief note which prefaces each article is not meant to take the place of a thorough analysis and study on the part of the student, nor by any means to encroach upon the prerogative of the instructor to deal with the material as he sees fit; it is designed merely to suggest to the student who may be using the book undirected by a teacher some of the elements which might well be observed.

Principles of Technical Description

Technical descriptions of machines, apparatus, generating plants, and other objects of interest to engineers are usually expositions inasmuch as the writer's fundamental aim is, in the majority of cases, merely to make clear the appearance of the object described and sometimes its method of operation. He is, in other words, explaining, and he is not usually concerned, as is the writer of artistic description, in recreating in the mind of the reader a reflection of any emotion which the object has aroused in him. His primary aim is to reproduce in the reader's mind a mental image of the object described, or at least of its essential features. His secondary aim, if he is an agent or a salesman, or enthusiastically interested, may be to convince the reader of the good qualities of the thing which he is describing; and this aim may affect his method of presentation. Obviously the best method to follow in technical description is an actual exhibit and demonstration of the object to be described; hence the ubiquitous salesman and his "line" of samples. But in a great many cases the only means of reaching the reader is by writing to him or for him, of making as clear to him as possible at long distance just how a machine or a factory looks. The writer must ordinarily assume that his reader is not familiar with the object to be described; he must leave him with a clear visualization at least of its essential features. It is quite legitimate, then, for the writer to use any device or trick which will assist his reader to see the object clearly. The specific problems which confront the writer of technical description have to do with the methods of creating an image in the reader's mind and the questions of how much to include and of how to arrange the details in a given description.

In making clear to the reader the exact appearance of any object no written description, no matter how carefully worded, can perform the same office as a photograph, sketch, or diagram. A graphic representation gives, in fact, a mental image which might not come to the reader after the perusal of pages of written description. It is natural for any one who is attempting to make clear the appearance of a thing to say, "See, this is the way it looks," and then to attempt a drawing of the object. And just as naturally the reader expects this to be done. In addition to assisting the reader to form a correct mental image of the object being described an illustration or diagram of any sort provides a welcome relaxation from the reading. Few readers are so constituted that they can read page after page of difficult technical description, understandingly, without fatigue; illustrations provide relief. Because, then, of this twofold value of illustrations, no writer of technical description should fail to make use of them whenever it is serviceable to do so. This does not mean that short descriptions of simple objects should be overloaded with unnecessary illustration, or that any article should contain illustrations which have little or no connection with the description. It does mean, however, that the writer should not fail to use a graphic illustration wherever it will be of real assistance to the reader.

However valuable illustrations of various kinds may be, it should be remembered that they have limitations. There is much that even the best of them cannot do, and the worst of them may actually mislead the reader. In fact, they can seldom, if ever, be used without an adequate accompanying explanation, and the practice, therefore, of forgetting that they are at best supplementary to the exposition and of depending upon them and reducing the written explanation to an unintelligible minimum is pernicious. To describe a machine merely by showing a photograph or drawing of it is but to take a single step in the explanation. The reader wishes to know what the essential parts are, how they are related one to another, what the method of operation is, and a score of things which an illustration alone can not give him. The illustration, then, should ordinarily be used merely as a convenient supplement to the accompanying exposition. The most which can be done is, by means of letters and figures marking the various details, to use it somewhat as a demonstrator uses an actual machine; but even in this case the explanation must not be lacking.

A few general suggestions to be followed in using visual devices of various kinds have already been given in Chapter II. These may fittingly be amplified here since it is in technical description more than in any other form of engineering exposition that illustrations are most useful. First of all, if an illustration is to be of the most service to the reader, it should be placed close to the explanation to which it belongs, if possible on the same page so that the reader may look readily from explanation to illustration. An illustration should show clearly the essential parts of the object described. For this reason a schematic outline drawing in which comparatively unessential parts have been omitted or unemphasized is often better than a more complete illustration. All illustrations should be neat; a messy drawing may be misleading or at least displeasing. Accuracy is another essential; a sketch which is incorrect, or out of proportion, or badly drawn may be worse than none at all. Illustrations should be set off distinctly from the text. An ample margin around a drawing is better in appearance than a narrow one and prevents words or phrases used in connection with the illustration from running into those surrounding it. Where the drawing is at all complicated and is referred to freely in the accompanying explanation, it is well to label the parts referred to with letters or figures. Such symbols should be orderly in arrangement and easy to find, and should leave no doubt as to the detail of the machine which they mark. A tabulated list of symbols and parts beneath the drawing often makes reference more easy.

Another method of assisting the reader to visualize the object, a method similar in its results to the actual use of a graphic illustration, is the comparison of the thing described to an object or form already familiar to the reader. How often and how naturally this is done may be seen from an examination of terms in common use, the T-square of the engineer, the trough of a valley, the S-hook of the machinist. Such a comparison results in the reader's perceiving in a flash, because of his familiarity with the known member of the comparison, the general shape or fundamental image, as it is sometimes called, of the unknown member. In making use of this device the writer should take two precautions. First, the unknown member of the comparison should be likened to an object with which the reader may reasonably be assumed to be familiar. If, for example, the reader has never seen a fish-hook, General Sherman's famous comparison of the Bay of Monterey to one of those implements will be quite lost on him. A second precaution is that the known member of the comparison have a form which is reasonably constant. To compare a recording instrument, for example, to a clock does not help the reader a great deal since clocks are of various shapes and sizes. To compare an instrument to a gentleman's open-faced watch, however, gives the reader a very tolerable idea of its general shape and size. The writer should not go too far afield for his analogies. A new type of machine, unfamiliar to the reader, may be compared with an older type with which he is familiar. Such a comparison does not take the reader far from the immediate subject.

Besides having the problem of getting the reader to see clearly the object described, the writer of technical description has the problems of selection and arrangement of the details of the description. Where the object to be described is very simple in construction, the difficulties of selection and planning are correspondingly few; where, however, it is a complicated piece of machinery or an extensive manufacturing plant, the problems may be puzzling. In the suggestions which follow it is assumed that the writer is attempting to write merely a clear explanation and not a persuasive exposition or an argument.

The details selected will depend, of course, largely upon the length of the description and the complexity of the object described. In a short description of a very simple piece of apparatus there is very little selection to be made; practically all of the parts can be included. This is not, however, true in the description of a complicated machine. Here to attempt to include every screw, and pinion, and spring, and bolt would result in the reader's getting anything but a clear conception of the machine. In patent office descriptions it is necessary to be very exact and detailed; in most other descriptions, however, it is better to make a careful analysis of the object with the view of selecting for inclusion in the description only the essential parts. A mere catalogue of parts is not a description any more than a pile of junk is a machine. The writer should usually aim to give his reader a mental image of the whole object and of the parts which are really essential; to attempt to do more than this is unwise unless the description is long, detailed, and very fully illustrated.

The problem of arranging the parts of a technical description is more difficult than that of determining what to include. The plan of the body of the description will naturally vary with the subject and with the specific aim of the writer. Certain general principles, however, should almost invariably be followed, and these will be explained briefly.

To begin with, since the writer of a technical description is attempting to see each detail of the object described in its relation to the whole and to other details, it is naturally necessary to give first some idea of the appearance of the whole object before plunging into a description of the parts. The necessity of doing this may be made clearer by a simple analogy. If a teacher of geography were to attempt to sketch a map of England by drawing the Thames and the Cheviot Hills and a few chief cities without first drawing the general outlines of the country, his pupils would be quite unable to relate these details to the whole or even properly to one another. A writer of a technical description who begins with details without first giving an idea of the general appearance of his subject will similarly confuse his reader.

Another general principle which will often be found valuable is that of giving at the beginning of the description a clear statement of the operating principle of the object to be described or of the purpose for which it was designed. With the general operating principle or the use clearly in mind the reader is better able to understand the appearance and function of the various details, for he has a key to them. On the other hand, the failure to begin a description with an explanation of the operating principle very often results in confusion or lack of understanding. For this reason (as well as for others) the following technical description is defective:

Bee Exposure Meter[1]

1. The Bee Exposure Meter is a small, nickel-plated, watch-like instrument used by many amateur photographers to find the correct length of time to expose their plates or films for different intensities of light. 2. Many plates and films besides many valuable pictures can be saved by the use of this simple meter. 3. It is easy to operate, and almost any person, regardless of his education, can operate it very successfully. 4. The meter has about the same size as an Ingersoll Junior watch, but it has no hands nor stem, a different dial, and the crystal instead of resting in a frame on the outside of the case is loosely set in. 5. In place of the small second dial on the watch the meter has a hole cut in the dial, which has the right one-half covered with grey paper and the other one-half a movable disc so a new portion can be exposed as often as needed. 6. The numbers on the left half of the dial represent the number of the U. S. stop used in taking the required picture, and the other half the time required to change the movable one-half of the small circle to the same shade as the grey paper. 7. Around the outer edge of the front is also a row of numbers. 8. Those numbers on the left represent the speed of the film or plate used, and those on the right the time needed to give the correct exposure for the picture. 9. The back of the meter is movable and can be rotated at the operator's will. 10. The first thing to do in operating the meter is to rotate the back and turn a new, unused portion of the movable disc in place, and time it to see how long a time is required to change it to the same shade as the grey color. 11. Then look up the sensitiveness or speed of your film or plate in the table supplied with each meter. 12. Press the thumb against the crystal and the first finger against the back and rotate the outer portion of the frame until the number of the speed on the left hand side of the frame corresponds with the size of stop on the left hand side

[1] The sentence numbers were added for convenience of reference.

of the dial. 13. Then opposite the time on the right side of the dial find the correct exposure for the picture on the right side of the frame.

This description would be very much clearer if the writer had explained at the beginning that the Bee Exposure Meter measures the intensity of light by determining the length of time required to bronze an exposed portion of white sensitized paper to a uniform fixed shade. With the operating principle thus set forth the present unintelligible details in sentences 5, 6, and 10, with the references to the "new portion" and "the same shade as the grey paper," would become more understandable. If the details of the instrument are described in terms of the general operating principle,—if, for example, the grey paper hemisphere is said to provide a fixed shade and the revolving disc to be the sensitized paper, a small portion of which can be exposed without exposing the whole, the description will be still clearer and more compact. As it is written, however, the writer has approached his subject too indirectly and has left too much to the reader's inference.

Very often the general appearance of the object, its use, and its operating principle may be made parts of a general definition. Often, in fact, one of the best ways to begin a technical description is in this way. A definition may be short,—a single sentence only,—or it may be long,—an entire paragraph or more,—and developed with considerable detail. In any case it is not a definition unless it really defines, that is, unless it really differentiates the object from others in the same or in a similar class. The following attempt at a definition is much too empty and shallow: "A micrometer caliper is an instrument used extensively in shop work." This is not very much better than the famous definition of thunder as "a noise heard by persons not deaf." There are scores of instruments "used extensively in shop work," and merely to classify the micrometer caliper with them is not going very far toward giving the reader an understanding of its appearance, specific use, and principle of operation.

It will be understood from the general principles of technical description which have so far been set forth that the method of presenting details which is most logical and psychologically the most sound is usually that of giving general ideas first,—definition, general appearance, principle of operation and use,—as a basis for an understanding of the details which are to follow. The organization of these details in the body of the description will, of course, vary considerably. In fact, every object which is to be described must be subjected to an analysis to determine the best arrangement of details for presentation in the description. Sometimes the logical order readily suggests itself. In the description of a factory, for example, the best way is usually to follow the course of the article manufactured. In describing a hydro-electric power-plant, similarly, the writer will usually find that the obvious plan to follow after he has given some general idea of the layout of the plant and of the size and shape of the building, is to describe the dam and spill-way, the channel, the interior of the building, the generating units, and finally the transmission system. In descriptions of machinery it is sometimes well deliberately to explain how to assemble the machine. Sometimes in describing a machine in operation the logical method is to follow the power from the initial impulse to the work performed. Often an analysis of the parts into the stationary parts and the operating parts will be found useful. Almost invariably parts which coöperate in the performance of a definite operation should be grouped and described together. In all cases the writer should be careful in describing one detail of his subject never to refer to another detail which has not yet been described. All these suggestions for arranging the parts of a technical description are, it should be remembered, only suggestions. In every case the writing of a technical description should be preceded by a careful analysis of the object to be described with the aim of determining the surest and most logical method of making the object clear to the reader.

The problems of writing clear expository description are very often complicated by the added problems of producing in the reader's mind in addition to a clear, concrete image of the object, some impression of its beauty, economy, utility, or other abstract quality. These problems the salesman must deal with and the engineer who finds himself called upon to convince the prospective granter of a right of way that a steel tower is not unsightly. Their consideration belongs properly to a treatise on salesmanship or argumentation. In general, the writer who must leave his reader with an impression of a definite quality possessed by the object he is describing should do so by keeping this quality uppermost throughout the description. To do this he may have to select for especial attention those details of the object which embody best the idea of the particular quality being emphasized. The writer must determine in each case the extent to which the persuasive or argumentative element is to enter into the description.

STUDENT THEMES

[These themes are for class analysis. They are *not designed to serve as models.*]

1. The American Pedometer

The American Pedometer is a small watch-like instrument carried by many people to register automatically the number of steps they take and indicate it by the number of miles walked. It is about the size of a silver dollar and about four times as thick. It is nickel-plated and has a white dial with black numbers from one to ten. It differs from the looks of a watch in that it has only one hand and in place of the ring in the stem the pedometer has a small flat hook so it can be hooked over a belt or vest pocket.

When the back of the case has been removed, the entire mechanism of the instrument can be seen. There is a small, crescent-shaped brass weight attached to one end of a lever and a three-leaf spring, which acts on a small flat wheel, which is very finely notched on its outer edge. There is also a small spiral hairspring, which keeps the weight at the highest position of its stroke. Then also there is a snake-shaped regulator, which regulates the length of the step taken by putting it on a number corresponding to the person's average step. There is also a small knob to turn the hand by and six small brass cogwheels.

A person intending to use a pedometer after knowing his average step and having set the regulator at the proper place must hang it vertically in his vest pocket or on his belt so that the motion of his body will cause the weight to vibrate up and down. This up and down motion turns the small notched wheel at the end of the lever, and this in turn transmits the motion through a series of cogwheels to the one fastened on the hand. By the motion of the body the little pedometer automatically tells you how far you have walked.

2. The Speed Counter

In all instances where it is necessary to determine the number of revolutions per minute that a shaft or other object is making, the little instrument commonly known as the speed counter is invaluable.

Most machines have their revolving parts moving so rapidly that accurate counting with the eye alone is impossible. This device is therefore applied to the center of either end of the shaft, and the revolving disc held with the thumb until the second hand of the watch, which is held in the other hand, reaches a point that is easily remembered. The disc is then released, and the speed counter records the revolutions for as long a period as is desired. Half a minute is the time usually taken as in most cases it gives sufficiently accurate results, and the R.P.M. can be found by simply multiplying by two.

The instrument is a simple contrivance whose essential parts are a worm wheel, mounted on a stem; a gear, bearing the movable disc which meshes with the worm, and a stationary dial, usually divided into one hundred equal parts. When the dial is divided in this manner, the speed ratio of the worm to the gear, or the stem to the disc, is one hundred to one, which means that for every revolution of the stem, a mark on the disc will pass over one space on the dial; also for one hundred revolutions of the stem, the same mark will travel once around the dial.

The mark is emphasized by having on it a slight projection. The raised portion enables the operator to observe the progress of the second hand on the watch and still count the complete turns of the disc by feeling it each time that it passes under his thumb.

The stem is supplied with a rubber tip so as to make better contact with the end of the shaft.

The worm and gear are enclosed in a case of which the dial forms one side.

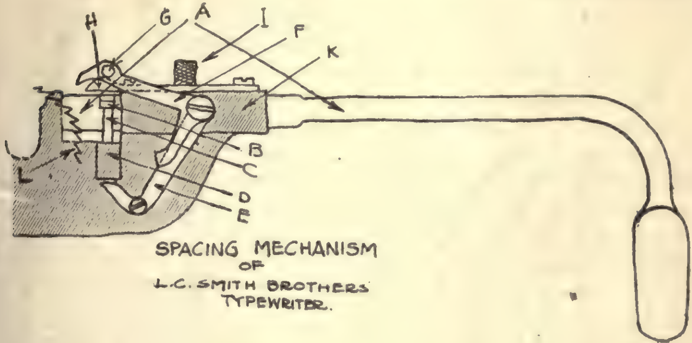
The speed counter complete does not exceed five inches in length and measures only one and one-half inches in the widest part. It is about the thickness of an ordinary watch, so it may be conveniently carried in the vest pocket.

3. The Spacing Mechanism of the L. C. Smith Typewriter

There is little essential difference in the spacing mechanisms of the various makes of typewriters. Only in the refinements of these mechanisms do we find real differences that differentiate one type from another. The special features of the L. C. Smith Brothers' spacing mechanism that would recommend it to our use are the easy access of the spacing lever from the keyboard and the constant-distance lever motion for all widths of spacing.

If we study the sketch shown, it is seen that the first feature comes from the shape of the spacing lever, which bends over the frame in such a manner as to place the handle just above the keyboard.

The basis of the second feature will be seen from a study of the entire mechanism of spacing. Spacing is accomplished by a twisting motion of the lever, *A*, in which the right hand end is moved



SPACING MECHANISM OF L.C. SMITH BROTHERS TYPEWRITER.

back, away from the reader. This lever extends through the cast-iron frame, *K*, and carries at the rear a small projection, *B*, which, as the front part of the lever is moved from the reader, moves down and pushes down the pin, *C*, which slides in the bearing, *D*, and engages the elbow, *E*, at its lower end. The motion of the spacing lever is thus transmitted to the elbow, *E*, giving its upper arm a motion to the left. This elbow carries on its upper arm a second elbow, *F*, which is pivoted to the first elbow, and the upper arm of which engages the teeth of the rachet wheel on the platen and thus turns the platen until the lower arm of the elbow catches in the rachet wheel and stops the motion.

In order to regulate the width of the spacing, a small pin in the upper end of the elbow, *F*, is forced by a wire spring to follow a cam, *H*, and by changing the position of this cam, the moment in which the rachet engages its wheel is fixed. This cam is on the end of a small, flat strip, which may be moved back and forth between two screws, which work in slots in the strip. The milled nut, *I*, carries on its lower end a pin which fits a series of three holes in the frame under the strip, thus providing three positions of the cam for three widths of spacing of the platen. A spring under the nut insures its permanency in the desired position. The constant-throw feature enters the mechanism in the cam, which fixes, not the time when the rachet action shall end, but when it shall begin. The result is the ease that must inevitably follow from an infinite number of throws of the spacing lever through a constant angle.

4. A Standard Student Lamp

The university student does the greater part of his work in the evening, and thus is in need of the very best lighting arrangement that can be obtained. It was for accomplishing this purpose that the student lamp was devised. In appearance it is very much like a miniature of an old-fashioned street lamp, if the lamp part is imagined as being pivoted so as to be movable in a vertical plane. This gives one a vague idea of how the lamp looks, in that it consists of three principal parts: the base, the upright, and the lamp with shade and socket.

The iron base of the lamp is about five inches in circumference at the bottom, and is covered with green felt. In height it is about three inches, and is built up to a peak by a series of three smaller and smaller circular segments. This base is covered by thin sheet metal so as to give it a smooth finished appearance. Through the center of the base is screwed a U-shaped prong with a one-quarter inch hole drilled through the upper part.

The upright consists of a rolled piece of sheet metal one-half an inch in diameter and of sufficient strength to stand rigid and hold the socket and lamp. It stands about a foot above the top of the base, and has its ends opened out and bent into a U-shaped prong with a hole drilled through similar to the prong on the base. The prong on the lower end of the rod and the prong on the base are then sandwiched together so that their holes coincide, and a bolt is slipped through this hole, and a thumb-nut screwed on to hold the two pieces tightly together.

To the upper part of the upright is attached a smaller circular rod of the same size and shape as the upright, but only about two inches long. It has a U-shaped prong at the bottom with a hole through it, and is fastened to the upper U prong of the upright by a bolt in the same manner as the lower end of the upright was fastened to the base. To the upper end of this smaller rod is attached an ordinary electric light socket and lamp with the wiring cord from the socket running through the hollow upright and out at the lower U prong to the circuit plug. To throw the light down and concentrate it upon the object that the person is working on, a semi-circular tin shade, or reflector, is attached to the lamp by spring clips on a circular brass sleeve, which is slipped through a hole in the shade and riveted to the inside.

When assembled, the lamp is very convenient in that the movable joints can be bent in many attitudes and clamped in the desired position by means of the thumb-nut.

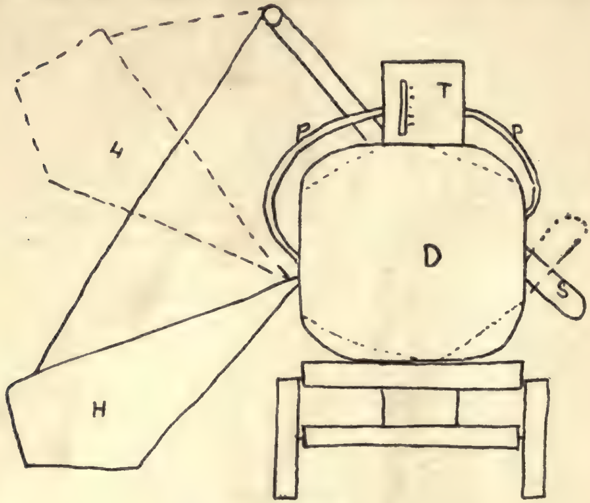
5. Batch vs. Continuous Concrete Mixers

Of the two classes of concrete mixers, batch and continuous, late practice is favoring the batch mixer as the superior. A batch mixer is one into which a properly proportioned mixture of materials is placed, mixed, and discharged in a mass. A continuous mixer is one into which the materials are fed continuously, and which discharges them in a continuous stream. The relative advantages of the two classes will readily be seen after a description of a general type of each.

A batch mixer consists primarily of a hopper, *H*, a power driven, revolving, spherical or conical drum, *D*, a water tank, *T*, and a discharge chute, *S*, all arranged as shown in the diagram. To mix concrete, cement, sand, and stone are placed in the hopper in their proper proportions. This is then raised, and the materials slide into the drum. The engine is started, and while the drum is revolving, the proper proportion of water is run into it through pipes, *P*. A series of blades in the drum churns and thoroughly mixes the materials. This takes about three minutes, after which the chute, *S*, is lowered, and the concrete will discharge.

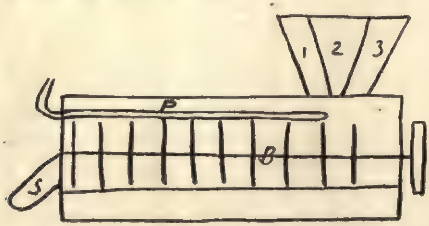
A continuous mixer has a hopper containing three chambers, 1, 2, and 3, into which cement, sand, and stone are placed respectively.

An opening in the bottom of each chamber is so arranged that the material in it falls through at a certain rate, thus forming the pro-



Batch mixer.

portioned mixture. A propeller-like arrangement of blades, *B*, carries the materials out through the chute, *S*. The intimacy of



Continuous mixer.

mixture depends upon the churning action of the propeller blades. Water is added by means of pipe, *P*.

The chief factor which influences good concrete is the proper proportioning of materials. That we gain this in the batch mixer, where just so much cement, so much sand, and so much stone are placed in the hopper and then mixed, there can be no question. On the other hand, in the continuous mixer, the rate at which materials flow through their hopper chambers depends partly upon their depth in those chambers; the greater the depth, the greater the gravity pressure, and consequently, the greater the flow. What is to prevent a foreman whose interests are too closely allied with those of the contractors from keeping the supply of cement rather low in its hopper? Another factor that must be considered is that moisture might cause caking upon the sides of the cement chamber and partly close its orifice. The effect of this upon the mixture is obvious. Thus we see that in the continuous mixer we cannot depend absolutely upon the proper proportioning of material, as we can in the batch mixer.

Another factor in making concrete is the amount of water used. In the batch mixer a definite, predetermined amount of water is allotted to each batch. This insures concrete of a uniform consistency. In the continuous mixer, on the other hand, water flows upon the materials continuously, and the rate of flow which gives the proper consistency is largely a matter of personal equation in the operator. The results are naturally not so reliable as the certain ones of the batch mixer.

In the batch mixer the thoroughness of the mix depends upon the number of revolutions of the drum. As the drum can be turned over any number of times, there is no danger of insufficient mixing. In the continuous mixer the thoroughness of mix depends upon the length of the mixing chamber. If the concrete comes out insufficiently mixed, there is no means of remedying this fact.

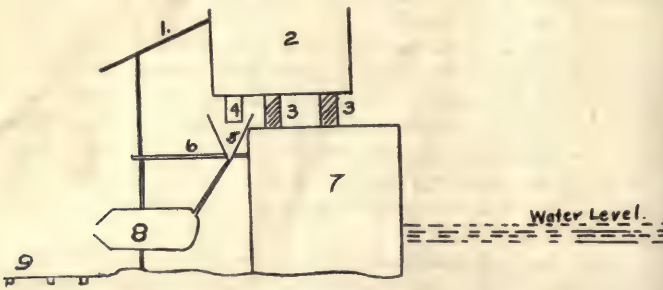
Thus it is clear that the machine which under all conditions will supply the better and more uniform grade of concrete is the batch mixer.

6. A Concrete Mixing Plant

When concrete is mixed in large quantities, the problem of handling the raw and the finished materials becomes a very difficult one. As concrete weighs about one hundred and fifty pounds per cubic foot, a mixing rate of forty-five cubic yards per hour means the moving of over ninety-one tons of material in that time, which presents a problem which even the layman can see is a very large undertaking.

The mixing plant which I am about to describe is now being used in the construction of a dam across the Ohio River, about sixty miles north of Cincinnati. The plant is situated on the north side and on the inside of a coffer-dam, which is now in the river for the purpose of facilitating the construction of the dam. The top of the wall, about ten feet wide, is sixteen feet above low water.

The plant can hardly be called a building, for it is open on all sides; yet it has a lean-to roof, for the purpose of protecting the cement bags from rain. Although the roof is of light material, the rest of the structure is rather massive, for the building must



1. Roof.
2. Storage bins.
3. Column supports.
4. Measuring boxes.
5. Hopper.
6. Floor.
7. Wall of coffer-dam
8. Mixer.
9. Track.

General layout of plant.

support the bulky concrete ingredients. The building is divided into three stories, the lower one being on the level with the river bed, the second one being even with the top of the dam, and the third extending above the top of the dam. The top story, which consists of storage bins, one for the sand and one for the gravel, is about the size of half a freight car.

Small openings in the bottoms of these bins connect the third and second stories. The second floor might be termed the mixing floor, for it is here that the sand, gravel, and cement are mixed. Two measuring boxes the sizes of which were determined by the proportions of the mix are placed under the openings from the storage bins. These measuring boxes contain removable ends, so that the sand or gravel can be quickly let down into them, measured, and dumped. The mixture falls into a rectangular hopper, which if filled would hold about a wagon-load of material. Four sacks of cement are dumped into the hopper, and the charge is ready for the mixer.

A signal is now given to a laborer on the first floor, who pulls a lever which lets the ingredients down through a chute and into the mixer. This mixer, with a small steam engine used to run it, and a cylindrical can for measuring the water, is about the only thing to be seen on this floor. A steel track, having a gage of three feet, runs up to the edge of the mixer, so that the concrete can be dumped into iron buggies running on this track.

7. The Atka Model Canoe

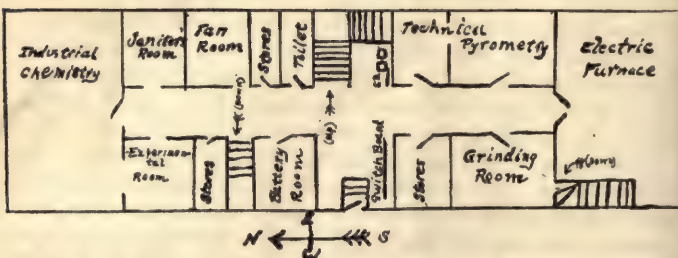
In selecting a canoe I wanted one for use on both rivers and lakes. This meant one that combined stability with ease of running and handling, thus making it equally useful on heavy seas and long river stretches. I found what I was looking for in one of the Old Town Company's late canoes, a seventeen foot Atka model.

This canoe weighs seventy pounds and is wide enough at the midportions to allow two persons to sit in the bottom side by side. The central half of the bottom is built very flat; this gives the canoe a light draught, which makes it easy running. From this portion the canoe is built, without losing its graceful lines, with a greater depth and a narrower beam at both stern and bow ends. These ends cut the water readily, and their depth and width of beam have the effect of creating a low center of gravity, causing great stability. The ends come up in graceful curves, viewed from the side, and are decked over about fifteen inches. These decks add greatly to the appearance of the craft. A good feature of the canoe is its open gunwales. The ribs come up between two strips of wood which form the top edge, leaving alternate spaces and rib cross sections. This makes it easy to keep the canoe clean, as it can be rinsed thoroughly, and every drop of water can be drained from it. The advantage over the ordinary closed gunwale, which always prevents a little dirty water from draining out, is obvious. Two horizontal braces at the third section, and the regulation seats complete the canoe.

The canoe is made of cedar planking built up around a frame of ribs attached to the bottom beam and the gunwales. This planking is of select straight grain wood, and each plank runs from one end of the canoe to the other without a break. All parts are nailed together with small copper nails. The whole is covered with stout canvas, which is heavily enameled with a water proof marine paint finished off with shellac. The inside is finished with a light colored water proof varnish.

8. The Basement of the Chemical Engineering Building

A long hallway runs north and south, the full length of the Chemical Engineering Building basement. This hall is reached



from the upper floors by a stairway in the middle of the building. At the extreme north end of the hall is a door opening into the Industrial Chemistry laboratory. This room contains, at the west end, two vacuum drying ovens standing up against the wall, and a vacuum evaporating kettle about ten feet out from the wall, resembling a huge black egg on legs. Between the two drying ovens are a small steam exhaust pump and condenser, which produce the reduced pressure for the three vacuum apparatus. About the middle of the north wall is an ordinary galvanized iron drying oven about six feet high, heated with steam pipes and having natural draught only. In the east half of the room are four filter presses of small size and representative of the commercial types in practical use.

Proceeding south along the east side of the hall, one meets first the janitor's room, which has a bench with several vises attached, a small polishing lathe, and several cupboards for tools; next the fan room, which has a medium-sized exhaust fan for ventilating purposes, and a small steam-driven air-compressor for supplying air under pressure to the various places about the building where it is required. Beyond this is a small store-room, a toilet-room, and then the stairway with a photographic dark-room beneath. Beside the stairway is a small switch-board and a motor-generator set. The next two rooms are given over to the course in technical pyrometry. In the first of these two stands a large glass case, filled with numerous electrical measuring instruments.

At the extreme south end of the basement is the electric furnace room. This room has a high ceiling, as it is beneath the large auditorium on the second floor. The circumstance of the high ceiling is quite fortunate in view of the volume of smoke and fumes that is evolved when the furnaces are in use. Along the north wall are a number of very large transformers, from which the power is led to the furnaces by cables of about half inch size. There are some six or eight electric furnaces of various types spread about the room in positions which change from time to time, according to the desires of whoever uses them. A stairway at the west end leads down into a very dark and musty sub-basement, used for the storage of such articles as are found too old and decrepit for use even by the Chemical Engineering Department.

As we proceed north along the west side of the hallway, we come next to the grinding room. On a low platform in the northwest corner of this room are about five or six small crushing machines, mainly of the jaw-crusher type. In front of this is a gyratory crusher, standing upright. In the northwest corner are a small fan and a miniature tube-mill, both belted to an over-head shaft. In front of these is a burr-stone grinder for fine grinding. In the southeast corner is the motor which drives the crushing machinery.

Next to the grinding room is another store-room, used for the storage of heavy chemicals and apparatus; and beyond this an enlarged space, in which stands the main switchboard for the building, and at the north end of the enlarged space is an outside entrance. The battery room comes next, with a number of rows of lead-storage cells in glass containers. After this is another stairway to the sub-basement, and then comes another store-room, in which are kept the pure chemicals, and then another room which is used for experimental work, and we are back again at the starting point.

TECHNICAL DESCRIPTIONS

A Convenient Method for Replacing Series Incandescent Street Lamps[1]

[The following short description is an example of the type of brief article frequently contributed by practicing engineers to technical journals,—merely a paragraph or two on some apparatus or practice likely to be useful to other engineers. The effective use made of photographs should be noted.]

Where series incandescent street lamps are installed at the end of long outriggers, attached to unstepped iron posts, it is customary to replace burned-out and broken lamps from a tower wagon or with a stepladder. The first method is quite satisfactory where there are hundreds of such posts in service. It frequently happens, however, that a lighting company has only a few of such posts to maintain, and these are often located several miles from the shop. In such cases the cost of operating a tower wagon is

Fig. 1.—Construction of device for replacing street lamps.

[1] Reprinted from the *Electrical World* for April 22, 1916, by permission of the publishers.

FIG. 2.—Method of using device to remove lamps from the ground.

prohibitive, and the use of a ladder is awkward and introduces an element of danger. By means of the device shown in the accompanying illustrations the night inspector can quickly and easily replace a lamp from the ground.

The construction of the apparatus is shown in detail in Fig. 1. A pair of tongs is fitted with semi-circular clasps that close around the lamp base, holding it rigid and allowing no lateral motion. These clasps press against the top of the base rim when the lamp is being removed. In returning the lamp to the receptacle a lug on each jaw fits under the rim and forces the lamp into place. About ¾-in. play between the clasps and the lugs permits of quick adjustment of the jaws in grasping the lamp base. It will be noted that no part of the device touches the lamp itself, so that it is as easy to remove a broken lamp as one that is burned out or blackened. The tongs in the particular outfit shown have been rounded out to allow clearance for lamps of the shape now manufactured in sizes of 250 cp. and over. The tongs are opened and closed by means of a rod running the length of the stick upon which they are mounted. This rod is attached to an insulated operating lever at the lower end of the stick. A tension spring controls the operating lever so that lamp base cannot be released even if the operator removes his hand from the handle. The apparatus was made at small cost by a local blacksmith, who used the stick and operating handle of an ordinary tree trimmer in its construction. The writer has found the device a valuable time and trouble saver.

The Mechanical Filter[1]

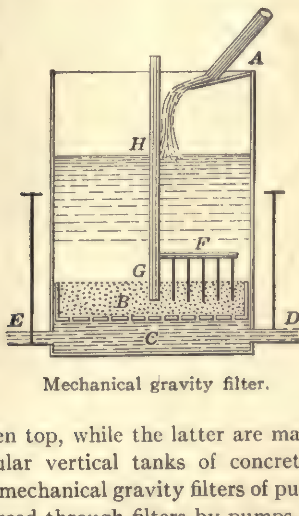
Mansfield Merriman

[The following brief description illustrates the use of the diagram to assist the exposition. The value of the diagram will be at once evident if the reader can imagine the difficulty of visualizing the filter from a mere verbal description, no matter how clear and accurate this may be.]

[1] Reprinted by permission of the publishers from pages 74–76 of *Elements of Sanitary Engineering* (John Wiley and Sons, 1909).

A mechanical filter is one that is operated by power and strains the water at a rapid rate through sand or other suitable material, afterwards discharging it into a basin, where sedimentation may take place. Alum is often employed as a precipitant, this being added in the form of a solution before the water enters the filter. Mechanical filters are frequently used in hotels and hospitals, as also for the public supplies of towns and small cities.

The mechanical filters used in America are quite similar in principle, although they differ much in detail and arrangement. In some the water passes through under the action of gravity, while in others it is forced through by pumps, the former having wooden



Mechanical gravity filter.

tanks with an open top, while the latter are made of steel and are closed. Rectangular vertical tanks of concrete have been used since 1900 for the mechanical gravity filters of public water supplies. When water is forced through filters by pumps, steel cylinders are used, and these are sometimes arranged so as to be reversible in position. A general description of the method of operation of a gravity tank will render clear the principle of action of all American mechanical filters.

Imagine a cylindrical wooden tank, say 12 feet in diameter and 20 feet high. The water is brought into this tank through a pipe *A*, and by means of an apron is scattered so that it may receive some aeration. Near the bottom of the tank is seen a sand-bed, *B*, about two feet thick, contained in an iron box with a perforated bottom. The pressure due to the head above *B* forces the water through this sand to the chamber *C*, whence it passes through the pipe *D* to the settling basin. After a time, varying from six to twenty-four hours, according to the degree of impurity of the water under treatment, the sand-bed becomes clogged with dirt and the rate of straining is so slow that the process is stopped in order to clean and wash the sand. For this purpose the valve at *D* is closed and the chamber and tank are drained by a pipe not shown in the figure. Then the valve *E* is opened and water is forced by a pump into the chamber and upwards through the sand-bed; simultaneously the rake *F* is lowered into the bed and revolved by the axle *GH*, in order to thoroughly stir the sand. This dirty water is then drained off, and the cleaned bed is ready for the next operation.

While the above description does not exactly represent any particular mechanical filter, yet it is believed that it gives a fair account of the principles involved in all of them and of the general method of operation. A filter of the size stated generally delivers from 300,000 to 400,000 gallons in twenty-four hours, or approximately at the rate of 3000 gallons per square foot of surface per day. When arranged for the purification of a public supply a number of them are required, the pumps and machinery for all being driven by the same engine. There are in the market about six principal styles, each having special patents covering the details of arrangement and methods of washing. In all cases the principle is that of straining, supplemented by frequent cleaning of the strainer, and the natural process of removal of organic matter by nitrification is imitated but slightly.

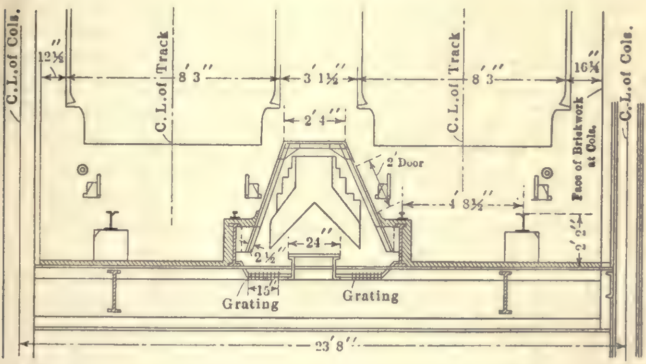
Sand-drying Plant of the Metropolitan Street Railway, New York[1]

[The following is an example of the type of explanation frequently encountered in technical journals, the description of the plant or engineering construction,

[1] Reprinted by permission of the publishers from the *Electric Railway Journal* for April 29, 1911.

completed or under way. Most of these are elaborately illustrated with photographs, sketches, plans, and diagrams. In the following brief description the use of plans and the underlying process-exposition involved in the explanation of the method of operation of the plant should be noted. A photograph has been omitted in reprinting.]

The Metropolitan Street Railway, New York, dries all of the sand required for supplying the car boxes and the sand cars operated on the entire system in a large rotary drier plant located in the basement of the new carhouse at Ninth Avenue and Fifty-fourth



Metropolitan Street Railway—Cross-section through dry sand conveyor.

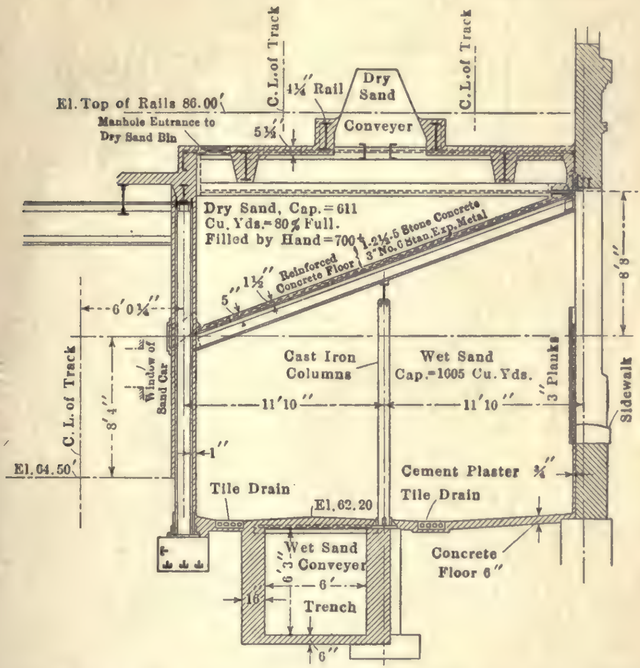
Street. From 200 cu. yd. to 300 cu. yd. of sand is required per week during the winter months, but the drier has a guaranteed capacity of 100 cu. yd. per day of 10 hours, so that ample reserve capacity has been provided. The wet sand bin will hold 1600 cu. yd. and the dry sand bin will hold 700 cu. yd. In addition to this supply about 1000 cu. yd. is stored under cover in a carhouse at Tenth Avenue and Fifty-fourth Street. This sand is available in case of emergencies when no fresh supply of wet sand can be obtained to replenish the bins in the Ninth Avenue carhouse.

The sand used is a fine sharp quartz, free from loam, pebbles and other foreign matters. It is dredged from the bottom of Long Island Sound and is delivered on barges in quantities up to 500 cu. yd. to a convenient pier on the North River. From the barges the sand is hauled to the Ninth Avenue carhouse in dump wagons having a capacity of 2 cu. yd. each. These wagons and their drives are furnished by the maintenance of way department, which keeps them at work at other times hauling track material. The wagons are backed in on the sidewalk of Fifty-fourth Street and the sand is dumped into any one of the seven openings in the north wall of the wet sand bin which occupies the center of the building on the Fifty-fourth Street side with the floor 4 ft. below the level of the sidewalk.

The wet sand bin is 65 ft. long, 22 ft. wide, 11 ft. high at the back and 18 ft. high at the front. The sloping ceiling, which is of reinforced concrete, forms the floor of the dry sand bin above. The floor is of plain concrete, 6 in. thick, and is sloped toward two longitudinal rows of tile drains which discharge the seepage water into the transfer table pit drains. The interior walls of the bin are formed of 8-in. cement-faced brick arches, built in between the twin channel columns. The seven dumping doors in the outside wall are closed with rolling steel shutters and removable plank gates are provided on the inside to relieve the shutters of any pressure when the bin is piled full. There are no partition walls in the wet sand bin.

A concrete tunnel 6 ft. wide and 5 ft. 8 in. high is built under the entire length of the wet sand bin to house the wet sand belt conveyor. Eleven hoppers in the floor of the bin discharge the wet sand onto the conveyor below. This conveyor has a 14-in. rubber belt which runs at a speed of 250 ft. per minute when both driers are being run, and at half that speed when only one drier is being run. The belt is driven by a 22-in. pulley on a jack shaft which in turn is belted to the main countershaft suspended from the ceiling of the drier room. This countershaft is belted to a 40-hp. C. & C. motor running at 535 r.p.m. When only one drier is being run the conveyor driving pulley shaft is belted to a second jack shaft so as to reduce the number of revolutions per minute by half and lower the speed of the conveyor to correspond with the capacity of the single drum.

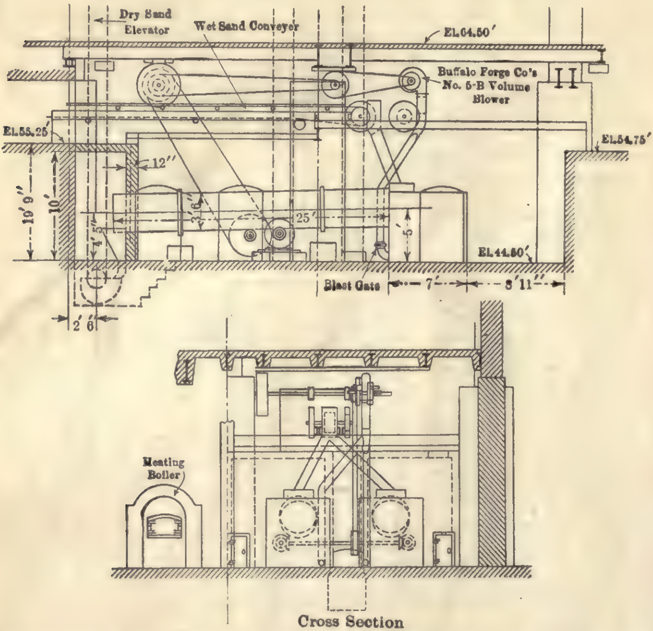
The wet sand conveyor discharges into a divided chute which drops the sand down into the front ends of the two rotary drying drums which are mounted on the basement floor, 20 ft. below the floor of the wet sand bin. The drier room is 46 ft. × 34 ft., and provides space for the steam-heating plant boiler in addition to the two drier drums and furnaces. The heating boiler and drier furnaces are designed to burn anthracite pea coal and storage space



Metropolitan Street Railway—Cross-section through wet and dry sand bins.

for 165 tons is provided in two vaults under the sidewalk of Fifty-fourth Street. Ashes are removed in cans which are hoisted on a hand elevator through a shaft opening onto the sidewalk.

The sand driers, which were furnished by the American Process Company, consist of a furnace for burning the coal and sheet-iron cylinder into which the hot gases from the furnace discharge under forced drafts. The drying drum or cylinder is 25 ft. long and 42 in. in diameter. On the interior are riveted a number of iron shelves which catch the sand at the bottom of the drum, lift it as the drum rotates and drop it at the top so that it falls through the blast of hot furnace gases. The drum rotates on two steel tires which rest



Metropolitan Street Railway—Longitudinal and cross-section of drier room, showing driving shafts.

on a pair of rollers driven through bevel gearing from the main countershaft suspended from the ceiling of the furnace room. It has a slope of 7 in. from the furnace end to the dry sand end and the wet sand hopper discharges into the upper end. As the drum rotates the sand is continuously raised and dropped through the hot gases, and the slope of the drum is sufficient to cause the sand to work its way slowly out to the discharge end. The rate of drying is regulated by varying the volume of hot gases sent through the drum by the blast fan. This fan is mounted under the ceiling of the furnace room and is belt driven from the main countershaft. The blast is controlled by slide dampers in the pipes leading to each furnace. Either drum may be rotated independently of the other by means of clutches on the bevel-gear driving shaft.

The two drums project 15 in. into a concrete flue chamber 10 ft. high and 4 ft. 9 in. deep at the discharge end, and the dry sand falls into a sloping hopper which carries it down to the hood of the dry sand elevator. The gases are carried off from this chamber through breeching which connects with the stack in southeast corner of the furnace room. The dry sand elevator is a 10-in. belt carrying buckets 8 in. × 5 in. spaced 24 in. apart and running at a speed of 232 ft. per minute. It lifts the sand to the level of the second floor of the carhouse and discharges it over a screen onto the dry sand conveyor, which distributes it to the dry sand bin. The distributing conveyor is a 12-in. belt running at a speed of 150 ft. per minute. It is housed in a dirt-proof casing built in between two storage tracks on the second floor of the carhouse and extends the full length of the dry sand bin. Continuous openings 15 in. wide and covered with coarse screens allow the sand to drop through into the bin from the spouts of the automatic tripper on either side of the conveyor track. The elevating and distributing conveyors are both driven by a 6.8-hp. motor, running at 816 r.p.m., which is mounted on the floor near the elevator head. Special care was taken in installing the dry sand conveyors to inclose them in dust-proof coverings so as to prevent fine dust and grit from being liberated on the second floor.

On the first floor a sand car loading track is built along the inside wall of the wet sand bins, and collapsible spouts with undercut gates are placed at intervals of 11 ft. 6 in. in the bottom of the dry sand bin wall. These spouts are designed to discharge the sand through the window openings of the sand cars, and they are spaced so that two spouts can discharge simultaneously into both ends of a car. The loading track will accommodate six cars at a time.

The plant requires one fireman, one laborer and a helper to operate it at its full capacity. One or both driers are operated for a full day's run for two to four days per week, according to the demand for sand. During May, June and July, 1910, 868 cu.

yd. of sand was dried at a cost of 15.87 cents per cubic yard. The labor charge for two men at $2 per day and one man at $1.75 per day was $65.35, and 57,590 lbs. of coal, costing $2.80 per gross ton of 2240 lbs., was burned. The total cost of operating the plant for the three months was $137.77.

The plant is operated under the direction of H. H. Adams, superintendent of rolling stock and shops of the Metropolitan Street Railway.

The Electric Burglar-alarm[1]

[Although written nearly forty years ago, the following article is a good example of a simple and clear technical description of a popular sort. Some of the expository elements to be noted are: (1) the enumeration of parts at the beginning, (2) the logical arrangement and clear division marks, (3) the use of illustrations to make clear the appearance and operation of the instrument, and (4) the inclusion of details, like that of cost, likely to be of interest to the general reader.]

Elaborate as are the ordinary agencies for the protection of property, they afford but a partial security. Well-lighted streets, careful watchmen, numerous policemen, and strong and ingeniously arranged bolts and bars, are certainly obstacles not easily overcome. But, in his quest of other men's riches, the accomplished burglar has not found them insurmountable. However extensive and vigilant a police force, it can not have all points under its surveillance at once, and this gives the burglar the opportunity which he rarely fails to improve. Bolts and bars are, doubtless, good things in their way; but the experienced cracksman has a cunning beyond them. In the contest between him and the locksmith, the victory has not always been with the latter, though he has produced that marvel of skill and workmanship—the modern safe-lock. The burglar's tools are not such as are thwarted by

[1] Reprinted from *Popular Science Monthly*, Vol. XVIII (1880), p. 56, by permission of the publishers. The use of the article was suggested by Fulton's *Expository Writing* (Macmillan, 1912).

nice mechanical combinations. Explosives and the simple mechanical powers in his hands have a wonderful range of utility, and are able to frequently set at naught the most elaborate contrivances. The protection afforded by these combined agencies is, however, only realizable to its full extent in the business centers of large cities. In residence districts, and in suburban and country situations where policemen are often few and far between, reliance has chiefly to be placed upon fastenings; and these often prove insufficient. Yet it is especially important for the owner of property that his protection be good, for recovery is very difficult. The advantages are so largely with the thieves, that they can frequently make the search a long and costly, and often a fruitless one. The cost is, in fact, the main bar to recovery. Only when stolen property is of large values does it pay to regain it. Small amounts, such as are usually taken from private houses, are practically irrecoverable.

No practical extension of the ordinary agencies can greatly increase present security. Bars and bolts have now approached very closely to their limit of strength and ingenuity, and police surveillance is as extensive and perhaps as effective as circumstances will permit. Greater protection must be sought in some further agency—one that will reproduce as nearly as possible the condition of watchfulness present in the daytime. This the electric burglar-alarm is designed to do, and does with a good degree of success. In its earlier forms there were many defects, but in a development of twenty years these have been mostly corrected. It has now attained a simplicity of construction and a certainty of action that make it one of the most useful and trustworthy of man's servitors. Though widely known and appreciated both in this country and abroad, there are probably many not acquainted with it, to whom a brief description will not be without value.

However the details of construction may differ, the essential elements of every system are: a bell to give the alarm, an annunciator to indicate the point from which it proceeds, wires from all the openings of a building, and a battery to furnish the current. The elements are combined in various ways, depending upon the special circumstances of the particular case, but the manner of use is practically the same.

The main piece of apparatus, remarkable alike for the simplicity of its construction and the range of its performance, is the annunciator. In the earlier forms of the alarm the indications were made by means of a simple switchboard provided with buttons bearing the names of the apartments protected. When an alarm sounded, the depression of each of these buttons in turn, until the bell ceased ringing, was necessary to determine its locality. This is still quite largely used, as it is cheaper than the more perfect annunciator, which tells at a glance where the disturbance in the circuit is. In shape and size this latter

FIG. 1.

instrument resembles an ordinary mantel-clock. The indications are given by devices on the face, which vary with different makers. In one form they are made by arrows, which lie horizontal when in normal position, and point to the names of the apartments printed above them when indicating. In another form, cards drop down in front of apertures arranged in rows on the face and in still another the name and number of a room are uncovered by a falling piece when an alarm is sounded. The needle-instrument is shown in Fig. 1. Once made, the indications remain until the parts are restored by some one. A small switch at one side completes or opens the circuit through the instrument, and one on the other side controls the connection with the bell. A row of studs at the base of the apparatus allows any opening to be disconnected that may be desired. Aside from its giving an alarm when an attempt is made to enter a building, the annunciator has an important use in showing whether a place is properly closed. If any window or door has been forgotten, it will infallibly point it out. In large business houses where there are many openings, this feature is of the greatest value. By disconnecting the bell, this test can be made a silent one.

The mechanism operating the indicators is of the simplest description. In the needle-instrument, an arm on the pivot of the needle is held in position by the hooked end of a lever, the other end of which forms the armature of an electro-magnet. The connection between the lever and the supported arm is very slight, so that a small movement of the former allows the latter to fall. When the circuit is closed this takes place. The armature in moving toward the magnet raises the hook end of the lever, releasing the arm which drops and turns its needle. In the instrument using the card, the card is carried on the end of an arm held up in a similar manner by a hook on the armature of the magnet. The depression of the armature allows the arm to drop by its weight. The restoring of the arms to position is done by a sliding frame raised by a handle or button on the base of the instrument. Delicate as the movements of the apparatus are, it is not easily put out of order. The points of contact of the hook and arm are so made as to reduce the wear to a minimum. The mechanism is all inclosed, and the exposed parts, such as the needles, switch-handles, etc., finished in polished metal. The annunciator and bell are usually combined into one piece of apparatus, but they may be put up separate when desired.

This secures the proper resetting of the apparatus in readiness for a new alarm. The result is obtained very simply by making the clapper turn a switch, which cuts from the circuit the open window or door, and allows the current to pass directly from the battery to the bell.

The door and window attachments for closing the circuit by the movements of these parts are of various forms. Those used on doors are simply little push-pins placed in the casing. The pin slides in an insulated case provided with metallic strips. When it is pressed in, the contact between it and the strips is broken and the circuit opened. When the pressure is released, the pin springs out, closing the circuit. The slightest movement of a door allows this motion of the pin to take place. In one form the pin and a metallic strip are so arranged that the attempt to keep the pin pushed in, when the door is opened, by inserting a knife-blade, establishes the circuit and gives the alarm. These push-buttons may be constructed to close the circuit, either by pushing in or springing out, and in both forms have a great variety of uses. They may be placed under the carpet, in the hall, on the stairs, in front of a window, or wherever any one entering would be liable to step. A sufficient number properly disposed could make intrusion without giving alarm simply impossible. The window attachments are usually simple springs placed in the casing so that the movement of the sash presses them together. One form consists of a roller on the end of a spring arm, which keeps it pressed out from contact with a metal strip, through which the circuit is completed. Placed in the casing, the roller stands out and is received in a pocket in the edge of the sash, so that the motion of the sash brings the roller arm and metal strip into contact. For the purpose of ventilation the pocket in the upper sash is usually elongated to give a free movement through any desired distance. When the lower sash is left open, security can be gained by covering a push-pin in the window-sill with a flower pot or other obstruction, the removal of which is necessary to gain entrance. The wires forming the circuit are of insulated copper, carefully put up so as to be completely hidden from view. They are run in grooves in the wood-work, carried beneath a floor, or on its surface according to circumstances. Once in place, they remain unchanged for any period, causing neither trouble nor expense.

The Le Clanché battery is the one universally employed with this apparatus. It is very simple in construction, exhales no noxious gases when in operation, does not waste the material when no current is passing, and needs but very little attention. The positive pole is a piece of gas carbon placed in a porous cell filled with coarse-grained peroxide of manganese and carbon. The cell is sealed at the top with pitch, and a lead cap on the carbon receives the wire. The negative pole is formed with a rod of amalgamated zinc. Both poles are immersed in a solution of salammoniac contained in a glass jar. Four of these elements put up in a wooden case constitute the battery usually furnished.

The bell used is that common with different forms of electrical instruments. It consists of a gong and a clapper vibrated by the combined action of an electro-magnet and spring. The magnet, when the current passes, draws the clapper to itself and in doing so opens the circuit; this destroys its magnetism and allows the

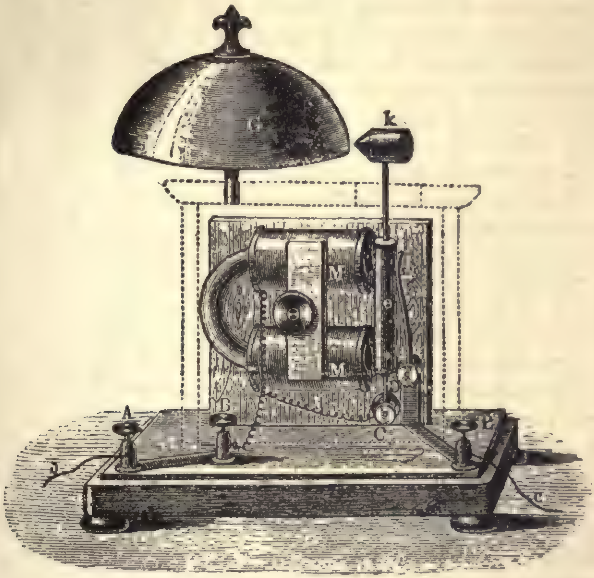


FIG. 2.

spring to carry the clapper back. This "make" and "break" action, rapidly repeated as long as the current is passing, produces a continuous ringing of the bell. Reference to Fig. 2 will make this movement clear. One end of the wire of the coils of the magnet M M is secured to the binding-post B, and the other to the post C. The arm of the clapper *k* is a rather stiff spring, which in its normal position holds the armature *e* carried by it from the poles of the magnet. It then presses against the spring *r*, attached to the post

D. The post A and E holding the wires from the battery are respectively connected with B and D by metallic strips. The current enters at A, traverses the coils of the magnet M M, passes through the armature *e*, and out by way of spring *r* and posts D and E. In doing so, the soft-iron cores of the magnet are magnetized and attract the armature *e*. This in moving breaks its contact with the spring *r*, and interrupts the current. The clapper then springs back into position. In the bell now generally used the ringing continues not only while the door or window is open, but until the indicating parts of the annunciator are restored to position.

These appliances provided, the most common way of using the system is to make it complete in each building, the alarm apparatus being placed in a sleeping appartment in a private house, and in the watchman's room in a place of business. So arranged, the condition of the circuit is this: In the daytime, when the doors and windows are open, the circuit is continuous at all points except at the alarm apparatus. At night this is reversed, the circuit being closed at the instrument, and broken at all the points protected. A movement at any of these points which closes the circuit gives the alarm and turns the proper needle in the annunciator. The connection with the alarm is made at night by an attendant, and broken at any desired time in the morning. In private houses fitted with electric bells, a clock is often provided that disconnects the alarm in the morning and turns the current on to a bell placed in the servants' rooms. The movement by which this is done is something similar to that of the ordinary alarm clock.

The protection afforded by such apparatus in good working order is probably as perfect as it can be made. It is generally impossible to cut the wires from the outside of the building, and unless this is done intrusion will start the alarm. Even if the wires be cut, buttons under the carpet or circuit-closers in interior doors will reveal the burglar's presence in perhaps every case.

Valuable as is the protection in any particular case of attempted robbery, the general immunity from such attempts that the presence of the apparatus secures is of still greater moment. Burglars will not generally take such risks as those imposed by an efficient alarm system, and will therefore give a house so protected a wide berth. The only case in which there is room for failure of the system is when the battery power is not sufficient to operate the alarm.

But it is a very simple matter to provide against this. Tests once every month or two, and the experience soon gained in using the battery, will enable one to know at any time the state of the system. None of the other parts need ever cause any solicitude.

While in the great majority of cases the plan of giving the alarm to some one in the building broken into affords perfect security, in some it does not. In business centers, determined and cunning burglars, accustomed to take large chances, might frequently overpower the watchman and stop the alarm before it excited outside attention. To meet this difficulty the plan is sometimes adopted of making the alarm sound in a central office of the company furnishing the apparatus. One company doing this has adopted a system that seems to be beyond circumvention. Each building protected is connected on a closed circuit with the central office, at which place delicate galvanometers are used as indicators. The circuit of each building is independent of all others. Any change in the resistance of any circuit is instantly shown by the deflection of the proper needle, and an alarm started. The opening of a protected door or window breaks the circuit, as does the cutting of the line, and of course gives an alarm. If the burglar could carry the wire to the ground and insert just the proper resistance, no signal would be given at the company's office, but this is impossible, as the resistance is not only that of the wire but of the apparatus in circuit. The only way to get around it is to tunnel under the building, but even then circuit-breakers judiciously disposed would generally lead to detection. Nothing is gained, so far as the safe is concerned, in this case, as it is independently protected. It is placed in a light wooden cabinet lined with a metallic casing, consisting of two sheets of tin-foil insulated from each other by a thin sheet of non-conducting material. The wires from a battery are connected each with one of the sheets of foil. So delicate is the insulation that the sticking of a pin in the cabinet closes the circuit and deflects the needle, and sounds the alarm in the central office. This system, though not yet in extensive use, is gaining in favor among merchants having valuable stores of goods. A similar plan of protecting private houses whose occupants are away is practiced to some extent. The apparatus used in this case is much less delicate, and the protection therefore not so good.

The cost of applying the burglar-alarm to any house will vary in each case. It depends upon the size of the annunciator required and the number of openings to be protected. The prices charged by the different American manufacturers differ very little. Annunciators range in price from thirty dollars with four indications to one hundred dollars with twenty. The annunciator used should have as many indications as there are rooms protected. The cost of circuit-closers, including the placing in position and laying the wire, is three dollars a window when both sashes are connected. The same devices for doors vary from one and a half to two and a half dollars. In ordinary city houses it is only necessary to connect the windows and doors, front and back, of the first two stories and the opening in the roof. The entire cost will not generally exceed one hundred dollars. In the country the cost would of course be somewhat greater, in the average house probably between a hundred and fifty and two hundred dollars. The apparatus once in, the only expense is the maintenance of the battery. This will generally be very small, probably not more than a dollar a year. Considering the security gained, the outlay required is not excessive, and builders find that is fully made up to them in increased rents. It is not improbable that the apparatus will eventually be considered as necessary to the complete equipment of a house as now are water- and gas-pipes.

The Steam Engine[1]

George C. V. Holmes

[Holmes's *The Steam Engine* is one of a series of *Text-Books of Science* "adapted for the use of artisans and students in public and science schools." The didactic purpose of the book is apparent in the style of the selection reprinted. The general movement is from simple to complex, with the explanation of an easy laboratory experiment serving to make clear the basic elements and

[1] From Chapter 1 (pages 1–14) of *The Steam Engine* (Longmans, Green and Co., 1902). Reprinted by permission of the publishers. The use of the selection was suggested by Lamont's *Specimens of Exposition* (Holt, 1894).

essential principles of operation of the simple types of steam engine described later.]

The complete study of the steam engine is, in its nature, somewhat complex, involving as it does an acquaintance with the sciences of heat, of chemistry, and of pure and applied mechanics, as well as a knowledge of the theory of mechanism and the strength of materials. It is proposed, therefore, to begin this work by showing, in a very simple case, how steam can be used to do work, and then to proceed to describe an actual steam engine of the most modern construction but one which at the same time is remarkably free from complexity. When studying this description, the student will soon find out how it is that the perfect knowledge of the steam engine involves an acquaintance with so many branches of science; and the order in which these subjects must be studied, so far as they bear on the matter in hand, will naturally be suggested by the description.

FIG. 1.

Take a hollow cylinder (Fig. 1) of indefinite height, the bottom of which is closed while the top remains open, and fill this cylinder to the height of a few inches with water. Next cover in the water by means of a flat plate, or piston, which fits perfectly the interior of the cylinder, and then apply heat to the water; we shall witness the following phenomena. After the lapse of some minutes the water will begin to boil, and steam will accumulate at its upper surface between it and the piston, which latter will be raised slightly in order to make room for the steam. As the boiling process continues, more and more steam will be formed, and the piston will be raised higher and higher, till the whole of the water is boiled away, and nothing but steam is contained in the cylinder. Now this apparatus, consisting of cylinder, piston, water, and fire, is an elementary form of steam engine of the simplest kind. For a steam engine may be defined as an apparatus for doing work by means of heat applied to water; and it is manifest that the appliance just described, inconvenient and clumsy though it may be, perfectly answers to the definition; for the piston is a weight, and this weight has been raised to a certain height by the formation of steam from the water. Now the raising of a weight through a height is a particular form of doing work, and consequently this combination is an apparatus capable of doing work by means of heat applied to water.

If, instead of a simple piston, we had taken one loaded with weights, and applied heat as before, the result would have been similar but not precisely the same. The water would not have begun to boil so soon, and when it was all boiled away the loaded piston would not have risen to the same height as did the simple one. The reason of this will be amply explained in the chapters on heat. Supposing that, having raised the weight to the utmost height it would go, we then removed it from the piston, and wished to employ the apparatus in order to raise a similar weight to the same height, we should have to bring back the steam to its original condition of water. This we could do by removing the fire and by surrounding the cylinder instead with cold water. The result would be that the steam would all condense into water, and fall back to its original place, the piston following it, and everything would be ready for a fresh start. Now, though this apparatus answers the definition of a steam engine, it is, nevertheless, a very bad one, for the following reasons. The only kind of work it can do is the raising of weights through certain heights. When we want to repeat the operations we have to remove the fire and surround the cylinder with cold water, and then replace the fire, which is a most cumbrous process. While condensing the steam we made the cylinder cold, and a large quantity of heat is wasted in warming it again. Moreover, when, at the cost of a considerable amount of fuel, we have heated the water and turned it into steam, we allow the whole of the heat in the steam to escape into the cold water, and thus become wasted, though it is capable of doing much more work if properly used. Thus we see that our elementary engine is limited in its scope, clumsy in use, and extremely wasteful of fuel. It is in obviating these disadvantages that actual engines differ from the one we have described.

It will have been observed that this engine consists of four principal elements, viz.: the fire, or source of heat; the water, or medium to which the heat is applied, and by the conversion of which into steam the work is done; the cylinder with movable piston, which contains the water and steam, and which prevents the latter from escaping into the air when formed and becoming lost; and, lastly, the source of cold, or the water by means of which the steam was condensed and brought back to its original condition. The great majority of actual engines consist of precisely the same elements, more advantageously arranged, with the addition of certain mechanism for changing the straight line movement of the piston into circular, or any other kind of motion. This mechanism has also to effect other subsidiary objects which will be fully described hereafter. It should also here be mentioned that if, instead of condensing the steam by means of cold water, we had opened a temporary communication between the steam space inside the cylinder and the open air, we should have equally well succeeded in bringing the piston back to its original position, when, by introducing into the cylinder a fresh quantity of water, we could have again raised the weights.

In practice the arrangement adopted is as follows:

1. The source of heat, and the vessel containing the water to be boiled, are kept quite separate and distinct from the cylinder. These parts of the apparatus are called respectively the furnace and boiler. The steam is supplied from the boiler, where it is generated, to the cylinder where it is used, as it is wanted, by means of a pipe, called the steam pipe.

2. The steam, after doing its work in the cylinder, is led away through a second pipe, called the exhaust pipe, into the open air, or else to be condensed in a separate vessel kept quite apart from the cylinder, and which is called the condenser.

3. The cylinder, instead of being open at one end, and of indefinite length, is closed at both ends, and in length seldom exceeds twice the diameter of the piston.

4. The steam, instead of being used only on one side of the piston, is admitted alternately to and exhausted from each side in succession, so that when the engine is in use, the piston is constantly travelling backwards and forwards from one end to the other of the cylinder.

5. Suitable openings are made at each end of the cylinder to allow the steam alternately to enter and escape, and valves driven by suitable mechanism are provided in order to ensure that the admission and escape of the steam shall take place at the proper moments.

6. Instead of placing the weights to be lifted directly upon the

piston, a cylindrical bar or rod called the piston rod is attached firmly to the centre of the piston, and is continued through one end of the cylinder to the open air, so that the outside end of the rod moves backwards and forwards in a straight line, exactly as the piston does. By means of a suitable mechanism, which will be fully described hereafter, this straight line motion of the piston rod end is changed into rotary or circular motion, so that the engine can be used, not only for lifting weights up in a vertical

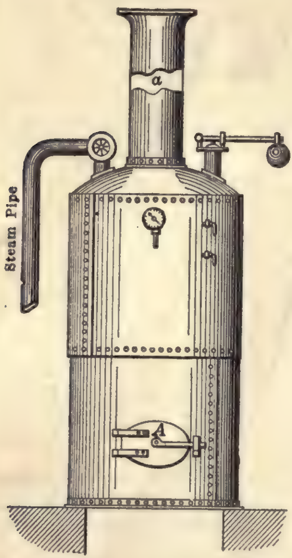


FIG. 2.

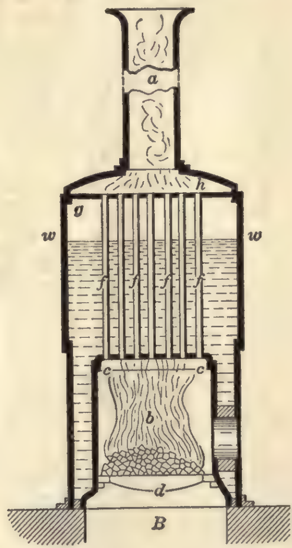


FIG. 3.

direction, but for doing any kind of work which may be required of it.

The manner in which all this may be accomplished in practice will be shown in the following description and drawings of an engine and boiler, which are here selected for description on account of their simplicity of construction. We will commence with the source of heat, and apparatus for turning the water into steam; then go on to the engine proper, *i.e.*, the cylinder with the mechanism belonging to it. The abstracter of heat, or condenser, will be considered in a separate chapter. Fig. 2 is an elevation of the boiler, Fig. 3 a vertical section through its axis, and Fig. 4 a horizontal section through the furnace bars.

The type of steam generator here exhibited is what is known as a vertical tubular boiler. The outside casing or shell is cylindrical in shape, and is composed of wrought iron or steel plates riveted together as shown in Fig. 2. The top, which is likewise composed of the same material, is slightly dome-shaped, except at the centre, which is cut away in order to receive the chimney, *a*, which is cylindrical in shape and formed of thin wrought-iron plates. The interior is shown in vertical section in Fig. 3. It consists of a furnace chamber, *b*, which contains the fire. The furnace is formed like the shell of the boiler of wrought iron or steel plates in the form of a cylinder, the top of which is covered by a flat circular plate, *cc*, firmly attached to the cylindrical portion by flanging and riveting. The bottom is occupied by the grating, on which rests the incandescent fuel. The grating consists of a number of cast-iron bars, *d* (Fig. 3), and shown in plan in Fig. 4, placed so as to have the interstices between them like the grate of an ordinary fireplace. The bottom of the furnace is firmly secured to the outside shell of the boiler in the manner shown in Fig. 3. The top covering plate, *cc*, is perforated with a number of circular holes of from one and a half to three inches diameter, according to the size of the boiler. Into each of these holes is fixed a vertical tube made of brass, wrought iron, or steel, shown at *fff* (Fig. 3). These tubes pass through similar holes, at their top ends in the plate *gg*, which latter is firmly riveted to the outside shell of the boiler. The tubes are also firmly attached to the two plates, *cc*, *gg*. They serve to convey the flame, smoke, and hot air from the fire to the smoke box, *h*, and the chimney, *a*, and at the same time their sides provide ample heating surface to allow the heat contained in the products of combustion to escape into the water. The fresh fuel is thrown on to the grating when required through the fire door, *A* (Fig. 2). The ashes, cinders, etc., fall between the fire bars into the ash pit, *B* (Fig. 3). The water is contained in the space between the shell of the boiler, the furnace chamber, and the tubes. It is kept at or

FIG. 4.

about the level, *ww* (Fig. 3), the space above this part being reserved for the steam as it rises. The heat, of course, escapes into the water, through the sides and top plate of the furnace, and through the sides of the tubes. The steam which, as it rises from the boiling water, ascends into the space above *ww*, is thence led away by the steam pipe to the engine. Unless consumed quickly enough by the engine, the steam would accumulate too much within the boiler, and its pressure would rise to a dangerous point. To provide against this contingency, the steam is enabled to escape when it rises above a certain pressure through the safety valve, which is shown in sketch on the top of the boiler in Fig. 2. The details of the construction of safety valves will be found fully

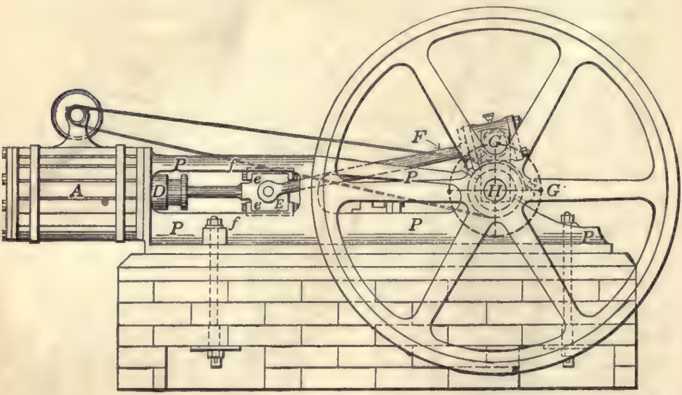


FIG. 5.

described in Chapter IX, which is devoted exclusively to the consideration of boilers and their fittings. In the same chapter will be found full descriptions of the various fittings and accessories of boilers, which it would be out of place here to describe in detail, such as the water and pressure gauges, the apparatus for feeding the boiler with water, for producing the requisite draught of air to maintain the combustion, and also the particulars of the construction of the boilers themselves and their furnaces, and the principles on which their strength is determined, and their various parts proportioned, so as to fully realise the effects intended.

We now come to the description of the engine, and the type selected for illustration is that usually called horizontal single cylinder, direct acting.

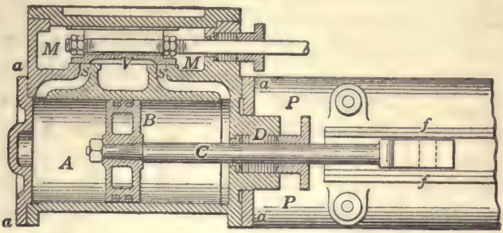


FIG. 6.

Fig. 5 is an elevation of the exterior. Fig. 6 is a horizontal section of the cylinder, piston, and valve box. Fig. 7 is a plan. The cylinder is shown at *A*, Figs. 5, 6, 7; its construction is best seen from the section, Fig. 6. It is formed of cast iron, the ends

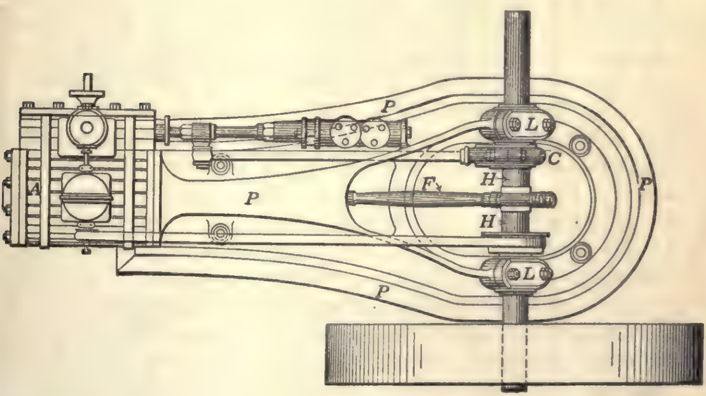


FIG. 7.

being flanged to allow of the cylinder cover or end plate, *aa*, and the frame, *PP*, being bolted to it. The piston is shown at *B*; it is a circular cast-iron disc, made to fit the cylinder in a steam-tight manner. Into the piston is fixed the piston rod, *C*, which passes through the front cylinder cover, the place where it passes through being made steam-tight by the stuffing box, *D*. The front end of the piston rod is fastened to the crosshead, *E* (Fig. 5), which is a joint used for connecting the piston rod to the connecting rod, *F*, in such a manner as to allow the latter to swing in a vertical plane as the piston travels backwards and forwards. The crosshead is also provided with two slides, *ee* (Fig. 5), which move between the guide bars, *ff* (Figs. 5 and 6), and which prevent the piston rod from being bent, and from moving otherwise than in a straight line. The connecting rod, *F* (Figs. 5 and 7), joins the end of the piston rod to the crank pin, *G*. The crank axle in which the crank is formed is shown in section at *H* (Fig. 5), but is seen more clearly in the plan, Fig. 7, where it is shown passing through the two bearings, *LL*. The distance between the centre of the crank pin, *G*, and the centre of the crank axle, *H* (Fig. 5), is called the length of the crank arm, and is exactly equal to half the distance which the piston moves from one end to the other of the cylinder.

Supposing now that steam were allowed to flow from the boiler into the cylinder in such a manner as to obtain admission behind the piston, *B*; this latter would commence to travel towards the front cover of the cylinder, and in doing so would push forward the piston rod and the crosshead. The end of the connecting rod next the crosshead would also be pushed forward, but the other end of the connecting rod which encircles the crank pin, not being free to move simply forward, would describe an arc of a circle round the centre of the crank axle, *H*, and in so doing the direction of the rod would become inclined so as to form an angle with the axis of the cylinder. By the time the piston has travelled to the front end of the cylinder, the crank pin will have been turned round into the position *G′* (Fig. 5), diametrically opposite to its initial position. Suppose that, just before this takes place, the steam is shut off from the back of the piston, and the steam already in the cylinder is allowed to escape, while at the same time fresh steam from the boiler is allowed to enter the cylinder at the *front* side of the piston, this latter will commence to travel back to its original position,[1] and in doing so will cause the crank pin to revolve from the position *G′* (Fig. 5), through a semi-circle, till it reaches its

[1]For the sake of simplifying the description, no account is here taken of the action at the dead centres. See p. 197. [Author's note.]

original position, it having thus described a complete revolution round the centre of the crank axle, while the piston was making a double stroke backwards and forwards. This operation may be repeated as often as we like provided we have a suitable apparatus for admitting the steam alternately on each side of the piston, and then allowing it to escape either into the open air or a condenser.

The manner in which the steam admission is regulated is as follows. By referring to the section (Fig. 6), it will be seen that a box-like casing, *MM*, is cast in one piece with the cylinder and on one side of it. This box contains the valve, *V*, which controls the flow of the steam. It will be noticed that the side of the cylinder next the valve box contains two passages, *ss'*; these are called the steam ports because the steam by means of them gains access to and escapes from either end of the cylinder. For the sake of clearness the following diagram, Fig. 8, is given, showing the

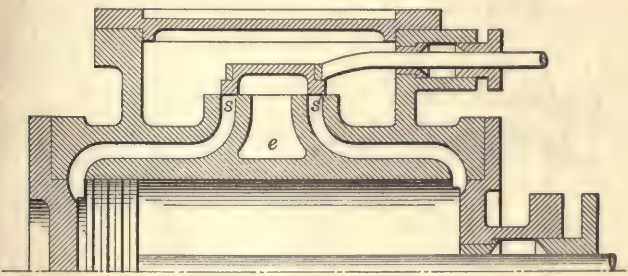


FIG. 8.

valve and side of a cylinder to a larger scale. The cast-iron box containing the valve is always filled, when the engine is at work, with steam from the boiler. If the valve occupies the position shown in Fig. 8, the steam can not enter the cylinder at all, because both ports are covered up by the valve. If the latter, however, be moved a little to the right so as to uncover the steam port *s*, two things will happen. The steam will be enabled to pass through the port *s* into the cylinder, and push the piston forward from left to right, while at the same time the port *s'* will be uncovered by the inner edge of the valve, and any steam which may be contained in the cylinder on the right-hand side of the piston will be enabled to escape through the port s' into the interior hollow of the valve, and thence into the exhaust passage e, whence it can escape to the air of the condenser. This condition of things is shown by Fig. 9.

If when the piston has reached the end of its forward stroke the valve be moved backwards into the corresponding position on the other side, the steam port s' will then be uncovered and will allow the boiler steam to enter the cylinder, and force the piston back from right to left, while the steam on the left-hand side of the piston will be enabled to escape into the exhaust passage.

The foregoing remarks must be looked upon as merely an elementary sketch of the working of this particular sort of valve (which is commonly called the *D* slide valve). The proper way of proportioning the parts of the valve, the widths of the steam

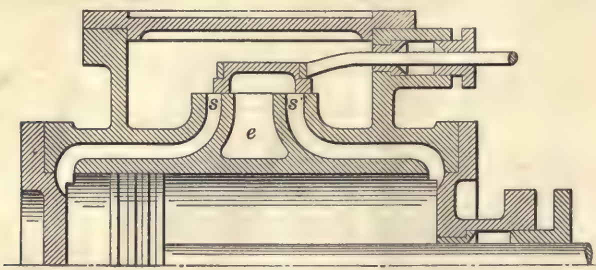


FIG. 9.

ports, and the methods of driving the valve so as to admit and cut off the fresh steam and release the exhaust steam precisely at the right moments during the stroke of the piston, are points of the greatest nicety and require the most careful study, and are fully described in Chapter VII; but enough has been now said to illustrate the method of working in a general way without going into complexities.

It will be noticed that the valve is connected by a rod (see Fig. 7) with a cam, *C*, fixed to the crank axle of the engine. This cam, which is called an eccentric, drives the valve backwards and forwards; its manner of working will be found described in the chapter already referred to.

When the centre of the crank-pin occupies either the point G',

Fig. 5, or the diametrically opposite position, the centre line of the crank is in the prolongation of the axis of the cylinder and connecting rod, and it is evident that when in either of these positions, which are called the dead centres, the steam would only tend to press the crank axle against its bearings, *LL*, Fig. 7, and would exercise no rotating effect whatever. Consequently unless some means can be devised for getting the crank over the dead centres the engine will stick fast.

The plan invariably adopted with a single cylinder engine is to provide a heavy fly-wheel, shown in elevation in Fig. 5, and in plan in Fig. 7. The momentum acquired by this fly-wheel during the stroke carries the crank over the dead centre. In addition to the above the fly-wheel exercises other useful functions which are explained in Chapter V, but which need not be dwelt upon at present.

The engine which has been described above is mounted on the heavy combined bed plate and frame *PPP*, shown in elevation Fig. 5, and in plan Fig. 7. The bed plate is bolted down to a solid mass of masonry as shown in Fig. 5.

For our present purposes it is not necessary to examine into the other details of the mechanism, such as the governor and feed pump shown on Fig. 7.

CHAPTER VII

EXPOSITION OF PROCESSES

Principles

Technical description, it was shown in the preceding chapter, is governed partly by the principles of ordinary description; it is, however, expository and not descriptive in aim. The exposition of a process has, similarly, some kinship with narration, since it deals with events in a sequential relationship; its aim is, however, distinctly expository and not narrative. The mind of the reader of a process-expositon strives to secure a clear understanding of the stages of the process and of their relationship one to another; this effort is intellectual and not emotional as it would be in the case of narrative. The exposition of a process differs from a technical description in the material dealt with. Technical description deals with concrete objects, which can be seen and touched; exposition of a process deals with the steps or stages in a process. Technical description is, in a sense, static; process-exposition is dynamic,—it advances from one point to another until the logical termination of the advance has been reached.

The writer of a process-exposition is faced by two questions,—first, What shall I include? and second, What shall the arrangement be? In process-expositions which are simple neither problem is very difficult of solution; in more complex explanations the second, especially, may offer some difficulties.

The question of what to include in the exposition of a process is related to the question of how detailed to make the exposition. The subject itself imposes certain general restrictions, but the writer may still be puzzled as to the fullness of treatment. This he will find to depend very largely upon his purpose. If the process is very complex, and it is his aim to give the reader merely a general idea of it, his explanation will necessarily be little more than an outline. If, on the other hand, he aims to give the reader an understanding of the details of the process, his exposition will, of course, be longer and more complex. The fullness of treatment is a matter which he must determine independently for each process-exposition. He should, it ought to be added, be especially careful in all cases to develop his subject *evenly*. This means that one process-detail should be given the same completeness of development as another process-detail of equal importance; if this is not done, the exposition will be out of proportion and will give a false impression.

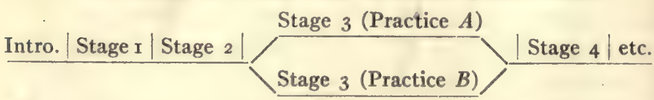
The problem of arranging the material of a process-exposition is simpler than that of any other expository type. In general, the organization is chronological, and the planning is to be done by stages or steps in the process. In the explanation of simple processes in which the various stages are unchanging in method and in sequence the parts of the exposition should come in a simple straight line; the explanation of the steps should be merely enumerative and sequential. Where, however, the process is complex, and two or more alternative methods must be presented, or where, as is often the case, two or more steps in the process go on simultaneously, it is necessary for the writer to carry one process-detail through and then return for the alternative or simultaneous detail. This practice is exactly like that of the novelist who, after dealing with one group of characters in his story, leaves them to turn to the adventures of another group, which have occurred "in the meantime."

These problems of arrangement may perhaps be made clearer by a series of diagrams:

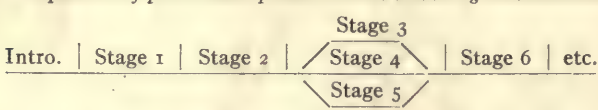
I. Exposition of simple process.

Intro. | Stage 1 | Stage 2 | Stage 3 | Stage 4 | etc.

II. Exposition of process with alternative process-details.



III. Exposition of process with process-details occurring simultaneously.



Process-expositions of Type I present little difficulty. With Types II and III comes the question, Which of the alternative or simultaneous details shall be taken up first? In the case of two or more alternative practices it is usually best to explain first that one which is the most generally employed, or that one which offers the best *building ground* for the others. This last means that two alternative process-details are rarely so entirely different that an explanation of one may not be used as a part explanation of the other. After completing the first explanation, the writer may usually say, "The alternative practice differs from the one just explained only in the following details," and then proceed to give only the points of difference. It is good compositional economy, therefore, to explain first the practice which offers the best basis upon which to build subsequent explanations. In the case of details occurring simultaneously the plan must be determined by the nature of the case. It is usually best here to take up first the most basic process or the one which links most closely with the preceding stage, and then to build the others upon this. In some cases the arrangement is of little importance so long as the explanation of each process-detail is clear.

It should be noted that in all these types the matter of clear and careful transition is of great importance. The reader should be told when a new step in the process is entered upon, and alternative and simultaneous process-details should always be carefully marked off from preceding stages. If this is not done, the reader may confuse one stage with another. Confusion may also result from the writer's carelessness in alluding in his explanation of one process-stage to details which he has not yet explained, or from his use of terms which he has not defined. He should remember the situation of the reader. The writer has in mind *all* of the steps in the process; the reader knows only those which have been explained up to the point reached in his reading. It is, accordingly, quite legitimate for the writer to build his new explanation upon details which he has already covered, as a child will build a pier into the water stone after stone; it is, on the other hand, quite wrong for him to depend upon the reader's understanding of things not yet explained. Sometimes it seems necessary to do this; where it must be done, the gap should be filled in with some such phrase as, "The specific function of this part of the machine will appear later"—a promissory note for what is to come.

There remain to be considered the introduction of the process-exposition, and the relation of the descriptive and the process elements.

The introduction of a process-exposition usually demands some special attention. It is seldom well to begin bluntly with an explanation of the first stage of the process; it is usually much better to give first some statement of the *general direction* of the whole process, with a definition and an indication of the object of the process and its underlying principles. This serves the same purpose in a process-exposition that a general introductory description of the whole does in a technical description; it provides, that is, a basic conception which assists the reader to a ready understanding of the relationship of each stage of the process to the process as a whole. A brief historical account of the evolution of the process may often be used effectively to give a better understanding of the reason for some of the process-details. The introductory elements mentioned are not, of course, of service in all process-expositions; it is for the writer to determine in each case whether or not they will be of value to the reader. In any case the introduction should not be over-long in proportion to the whole composition; and it should contain only material which will be of actual service.

It is obvious that in all explanations of manufacturing processes, descriptions of the plant and of the apparatus employed are likely to figure, and it is sometimes puzzling to know just how to combine these descriptive elements with the process elements. A mistake frequently made is that of giving all the descriptions first under the assumption that the reader can carry them in his mind while reading the explanations of the process-details which follow. Excepting in very short explanations this cannot be done. It is much the best plan to give at the beginning only a general outline description of the whole plant in connection with the outline exposition of the process, very much as the apparatus employed in a laboratory experiment will be briefly described at the beginning of a report on the experiment. Aside from this introductory general description all descriptive elements should be scattered through the exposition, being combined with the explanations of the process-details with which they belong. If this is done, there will be no improper dislocation of elements that really belong together. Illustrations, sketches, and diagrams should be employed to make these descriptions clearer, wherever such auxiliary devices will be serviceable. Various tricks may be used to indicate movements of parts, such as arrows and dotted lines, and the dimensions not shown in a plane figure may be indicated by perspective and skeleton drawings and by reference to parts lying in a direction "away from the reader." But as these tricks belong more properly to the science of the draftsman, they need not be taken up in detail here.

STUDENT THEMES

[These themes are for class analysis. They are *not designed to serve as models.*]

1. How Photographs are Made

In making a photograph it is first necessary to have a camera and a sensitive plate. The camera is a light-proof box, which has a lens inserted in one end. The lens is covered by a shutter which excludes all light from the box excepting when an exposure is being made. The sensitive plate is a glass oblong which is coated with certain chemicals which are differently affected by various intensities of light. This plate is held in the end of the camera opposite that which contains the lens.

The camera can be carried to any desired place, the shutter opened for an instant, and "the picture is taken." Light, reflected from the object being photographed, enters the box through the lens, is focused on the plate, and causes certain chemical changes on the surface of the plate, which make possible the following operation called developing. In a room illuminated only by red or dim yellow light, the plate is removed from the camera and placed in the developing solution. An image begins to form on the plate, which has, until this time, remained perfectly clear. The change goes on until all lines and figures are sharply defined. Then the plate is removed from the bath and is placed in the fixing bath.

The fixing bath removes all material from the plate which was not acted upon by the light and consequently not affected by the developer. The plate is then washed and set aside to dry.

We now have what is termed a *negative.* All parts of the object pictured which were white will appear black, and all black objects will appear white. The negative may be retouched to correct flaws or to remove harsh lines, or pictures may be printed without this extra work.

Printing consists in making positive pictures from the completed negative. In doing this the same dark room is used as before. The negative is placed in a frame, and a piece of sensitized paper is held firmly against its face. The frame is then placed in some bright light for a short time and returned to the dark room to be finished. Some papers require development much the same as a plate, while others need merely to be made permanent by immersion in one bath. Both varieties must be thoroughly washed and dried before they are finished.

When expensive work is being done, the prints are closely inspected, and all defects due to poor work or defective material are then obliterated with a small brush and dark oil paint.

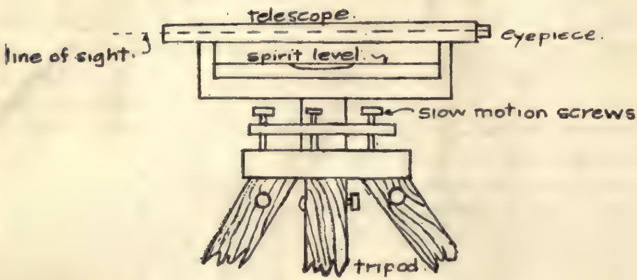
2. Leveling

The object of leveling, or, as it is often called, running levels, is to find the actual or relative elevation of a point or a series of points on the land. The method employed in this work is getting the elevation of the level instrument used by sighting on a rod held on a known elevation, and finding the elevation of a point ahead by sighting on the rod held on that point.

There are two different kinds of instruments used in this work, namely, the mounted level and the hand level. The hand level is used only for special work where accuracy is not a necessity, and it will therefore not be considered in this article. The mounted level consists essentially of a very finely made telescope about sixteen inches in length, which is mounted on three wooden legs known as the tripod of the instrument. The construction of the telescope to the tripod is such as to allow free horizontal revolution of the telescope about an axis perpendicular to its own axis, and to permit vertical movement of the telescope by means of adjusting screws. The general outline of the level may be obtained from the sketch.

In one of the lenses of the telescope are cross-wires placed at right angles to each other. One of the wires is truly vertical, and the other is truly horizontal. On the bottom of the telescope and rigidly attached to it is a spirit level. The object of this is to enable the levelman to keep the telescope truly horizontal at times when he is reading levels.

In running levels the elevation of the starting point must be known, or else an assumed elevation may be used. The order of procedure is as follows. The instrument is set up at a distance of about three hundred feet from the starting point so that the spirit level shows the telescope to be truly horizontal as it revolves about the vertical axis. This condition is accomplished by means of the slow motion screws (see sketch). The levelman now sights through the telescope on a rod which is graduated into feet and tenths of a foot and sometimes into thousandths of a foot, and which is held on the starting point. He reads the distance on the rod above the original point which coincides with the horizontal cross-wire in the telescope. This distance which he reads will give the elevation of the telescope when it is added to the elevation of the original point. Now the man with the graduated rod, generally



called the rodman, moves forward ahead of the instrument a distance approximately equal to the space between the first point and the instrument.

The rodman selects a point easily seen by the levelman and sets his rod up in a vertical position. The levelman now sights through the telescope again and reads the distance that coincides with the horizontal cross-wire. This distance, subtracted from the elevation of the telscope as previously determined, will give the elevation of the point over which the rod is held. The levelman takes up his instrument at this stage and sets up ahead of the rodman and repeats the program as explained above.

The foregoing is the general procedure when running levels.

The distance between the points the elevations of which are to be determined may be any distance, since, as explained above, the elevation of the telescope and the last point is always known, and the elevation of any point ahead may be obtained by taking a reading of the rod on that point, or, if the point is too far ahead, intermediate set-ups will be necessary.

3. Charging an Iron Foundry Cupola

An ordinary iron foundry cupola is about five feet in diameter at the base and is approximately forty high, the upper fifteen feet being cone shaped with a top diameter of about two feet.

The foundation, or part upon which the cupola proper rests, is made of iron and resembles an ordinary round topped table with four legs. The top of the foundation, which is the bottom of the cupola, differs from the top of an ordinary table in that it has a central two foot circular doorway into which a flanged door fits. The door is supported by heavy hinges and opens downward with the flange on the under side so that when the door is closed and locked, the flange will strike the bottom of the cupola proper.

The outside of the cupola is made of sheet steel, and it is lined inside with a double wall of fire brick to a height of about twenty-five feet or up to where the cone shaped top begins. The charge doorway, or opening for putting in the charge, is about twenty feet above the bottom of the cupola and about two feet above a second floor called the charge floor of the foundry, while on the first floor a trough to convey the molten iron away from the cupola is attached to it just below a small tap hole, which is about four inches above the bottom of the cupola. This part or side of the structure is called the front, and that part diametrically opposite is called the back. In the back of the cupola and about two feet above its bottom, is a hole through which an air pipe enters, and thus by forcing an air blast through this pipe, the cupola is furnished with a good draught.

In order to charge the cupola a good coke fire is built on the top of the table, or foundation, after which an amount of iron called a charge is placed on the coke through the charge doorway on the second floor. More coke is then thrown on the iron, after which more iron is thrown on this coke; thus the process continues, the charges consisting of alternate layers of coke and iron. When the furnace is filled to within a few feet of the charge door, the air blast is turned on, and as soon as the iron begins to melt, the tap hole is plugged with a ball of moist clay. After sufficient time to melt the lower charge of iron has elapsed, the clay is removed from the tap hole, and the iron is drawn off and poured into molds. When the lower charge has melted and has been drawn off, the tap hole is again plugged with clay. The contents of the cupola drop to the bottom, and the next charge begins to melt. It is then drawn off in a similar manner to that just described. Thus the process continues until all of the iron has been melted, after which the cupola is cleaned and recharged.

4. The Making of Pig Iron

Pig iron is made by reducing its ores with carbon at high temperatures. The ores, which consist of the oxides, are reduced in blast furnaces. These furnaces are cylindrical in shape and are from eighty to one hundred feet high and about twenty feet in diameter. They consist of a tube of iron or steel, which is lined with fire brick which has openings at the lower end. These openings are connected with tubes or tuyères to air blowers by means of which hot air can be forced through the furnace. To start the furnace, it is necessary to build a fire of coke in the bottom. The air is then turned on and the furnace charged from the top through a bell and hopper arrangement which prevents the gases and heat from escaping while the furnace is thus being charged. The charge consists of iron ore properly mixed with coke and limestone. The purpose of the limestone is to form slag with the impurities in the ore. No matter what the material added to the ore to produce the fusible slag, it is termed the flux. The charge is carried to the top of the furnace by some form of mechanical conveyor and then introduced into the furnace. As the air, which has previously been heated to about 800 degrees, is blown through the furnace, the charge becomes very hot. Carbon dioxide forms in the lower part of the furnace as a result of the burning of the coke. As the carbon dioxide passes through the hot layers of coke, it is reduced to carbon monoxide, which acts on the iron ores, reducing them to iron. The gases formed are still rich in carbon monoxide, so they are passed through pipes and used as fuel to heat the air blown into the furnace. Part of these gases are also used to run gas engines. The slag and iron settle to the lower part of the furnace in two layers, the heavier iron going to the bottom. The slag and iron may then be drawn off through tap holes. The molten iron is then poured into molds of sand and allowed to cool. These bars are known as pig iron, and are further dealt with to form steels and cast iron. The slag of the furnace is used in making Portland cement. The process can be made continuous if, as the iron and slag are drawn off, fresh charges of fuel, ore, and flux are added.

5. The Manufacture of a Mercury in Glass Thermometer

In the manufacture of a mercury in glass thermometer the principal operations are cleaning, filling, and graduating the glass thermometer tube. A small glass tube, like any ordinary thermometer tube with the end opposite the bulb broken off, is taken. This tube must first be thoroughly cleaned with some cleansing solution such as strong nitric acid. The bulb of the tube is heated, and then the open end is put beneath the surface of a mass of nitric acid. As the bulb cools, the nitric acid is drawn into the tube and bulb. When the tube has been filled, it is placed in a bath of boiling nitric acid and left there for several hours, or until the workman is positive that the tube is absolutely clean. Then it is taken from the bath and repeatedly heated and cooled until the last traces of the acid have disappeared. The tube is then ready to be filled with mercury.

To fill the tube with mercury the workman proceeds in the same way as he did when he filled the tube with acid, except that he must be more careful to get all air bubbles out of the tube. He fills the tube up to a desired level at a given temperature. This level is arbitrarily set by the workman, who knows at what range of temperature the thermometer is to be used. Having filled the tube to the desired height, he holds it in a vertical position and heats the bulb until the mercury has expanded enough to fill the tube nearly to the top. He then heats the open end of the tube until the glass melts and seals the opening. The thermometer is now ready to be graduated.

To graduate the thermometer one must have at least two fixed points on it and must know the number of divisions between these points. The Fahrenheit scale thermometer has two fixed points,—namely, thirty-two degrees, the point at which ice melts, and two hundred and twelve degrees, the point at which water boils under atmospheric pressure. The distance between the two points is divided into one hundred and eighty equal parts, called degrees.

To find the point at which ice melts, the workman immerses the thermometer in a mass of melting ice and water. After the mercury column has ceased to contract, the point which the top of the column has reached is marked on the glass tube. This point is at thirty-two degrees Fahrenheit, according to Fahrenheit's arbitrary scale.

Next, the workman finds the point at which water boils under atmospheric pressure. To do this he places the thermometer bulb and most of the tube in a container filled with water vapor (steam) coming directly from a bath of boiling water. After the mercury column has ceased to expand, he marks the point to which the top of the column has risen. This point is at two hundred and twelve degrees Fahrenheit. The distance between these two points is now divided into one hundred and eighty equal parts called degrees. The workman now etches the divisions and the numbers corresponding to each tenth division, such as 0°, 10°, 20°, etc., in the glass. The thermometer is now complete, and is ready to use as a temperature measuring device for temperature between thirty-two degrees and two hundred and twleve degrees. Its accuracy depends, of course, on the care taken by the workman.

6. The Laying of Underground Concrete Conduits[1]

Underground ducts are coming into greater and greater use in cities as a means of ridding the streets of all manner of electric wires and poles. Numerous kinds of ducts are being used, but it is the purpose of this article to describe the all-concrete ducts, and to explain the method of laying them.

Besides the concrete used, which is mixed at the scene of operations, other articles must be used in the laying of these ducts. Wooden molds, and chairs, weights, and slabs of concrete must be provided. The chairs are castings of cement and sand concrete

[1] The original outline of this theme is printed on page 36.

of about the form and dimensions shown in Fig. 1. The figure shows one used in laying ducts four in a layer. Three or six duct chairs may also be used. These chairs are used merely to support the molds in position until the concrete sets. However, they remain in position after the molds have been drawn as part of the system of ducts, so they must be supplied in numbers proportioned to the extent of the work in hand. The wooden molds are rods of Georgia pine about six feet long, and of a U-shaped cross-section that will

FIG. 1.

fit exactly one of the slots in the chair (*M*, Fig. 1). These molds are kept oiled to prevent the concrete from sticking to them. The weights are merely fifty-pound concrete blocks, about eighteen inches long, and provided with an iron handle to facilitate handling (see *W*, Fig. 3). The slabs used are, like the chairs, of cement and sand concrete, eighteen inches square and one inch thick. They too must be provided in considerable numbers, as they are incorporated into the duct system.

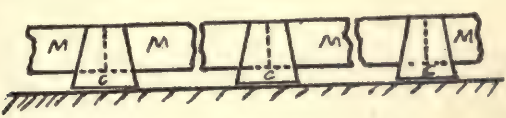


FIG. 2.

In laying the ducts, the first step is the excavation. A ditch some eighteen inches wide and from three to four feet deep is dug by the usual methods. Next, a layer of cement, sand, and crushed stone concrete is poured into the trench to the depth of two inches and carefully leveled and tamped. This is merely for foundation. When the concrete has set enough, in from ten to eighteen hours, chairs are placed transversely in the trench at regular six foot intervals. Molds are placed in the slots so that the arrangement is somewhat as shown in a side view, Fig. 2, *CC* being the chairs, and

MM, the molds. Weights, *W*, Fig. 3, are then put on at each chair to hold the molds down when the concrete is poured. Concrete used for the body of the ducts is made of cement, sand, and fine gravel. This concrete is poured rather thin and is allowed to fill completely the space under, around, and between the molds, up flush with the top, and over the sides of the trench. After the cement has set for about six hours, the weights are taken off, and the molds drawn. The slabs are then laid across the tops of the ridges between the ducts, one at a time. As each slab is laid, the crack between it and the next preceding one is carefully pointed with cement. To make sure that the ducts are clear after the slabs

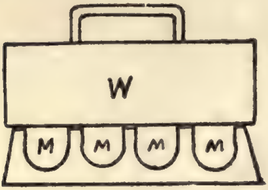


Fig. 3.

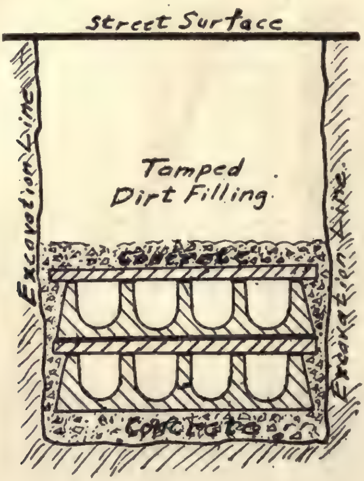


Fig. 4.

are in position, wooden plugs that fit the ducts are drawn through them, the length of one slab at a time, as the work progresses. On the smooth surface presented by the top of the slabs, other layers of ducts may be laid until the necessary number is reached. On top of the last layer another two-inch layer of cement, sand, and crushed stone concrete is added. When this sets, dirt filling is tamped in, and the surface of the street restored. A transverse section of a completed eight duct trench is shown in Fig. 4. These kinds of ducts are built only in straight, level runs, from manhole to manhole.

The concrete ducts are much less expensive than tile or fibre ducts, unless the cost of labor is abnormally high. It is claimed too that they form a more rigid system when in the ground, being practically monolithic; but this claim is doubtful as other ducts are usually set in concrete. However, where it is inexpedient to have too much street open at one time, concrete ducts must be ruled out. The time it takes for the successive layers to set would make progress extremely slow unless long runs were laid at one time.

7. Electroplating Non-metallic Objects

The electroplating of non-metallic objects, or the process of metallization, as it is often called, provides a fairly simple means of accurately preserving the orginal form of flower, insect, or other non-metallic object to which it is applied. The process might be termed a sort of three-dimensional photography, for the reproduction includes all of the details that would show in a photograph. and in addition possesses the advantages of form and depth. Photography is sometimes called scientific painting; the metallization process may just as correctly be termed scientific sculpture.

The essential steps in the process may be enumerated as follows: First, the selection and preliminary preparation of the specimen; second, forming upon the surface of the object an electrically conductive film of sulphide of silver; third, electroplating with copper this conductive film of sulphide of silver; fourth, removing from the copper shell thus formed the organic matter of the original object; fifth, cleaning the copper reproduction and giving it a pleasing appearance.

Considerable care must be exercised in selecting the specimen, for not all kinds of specimens lend themselves well to this treatment. The specimen should possess two main qualifications: first, it should be fairly firm, in order that it will hold its shape during treatment; second, inasmuch as recesses are hard to electroplate, it should be reasonably free from such defects. In the case of a flower it is always best to select a bud that is just opening out, and to remove any loose petals. The successful plating of a full-blown rose is possible, with a great deal of care and patience; but such success is extremely doubtful. Insects, such as flies, beetles, dragon-flies, etc., which do not possess too many hairs, lend themselves well to the process; but fur-bearing animals, or such insects as moths, butterflies, etc., which have a fine bloom on their wings, should not be attempted.

Having selected the specimen, one should next attach to it a fine copper wire, which will provide electrical contact for the electroplating process later on. For the purpose of covering the surface of the object with an electrically conductive layer of silver sulphide, one needs a solution of silver nitrate, containing about one ounce of the salt to the half pint. The silver nitrate should first be dissolved in as little water as possible, and the rest of the solution then made up with grain alcohol. The specimen is dipped in this solution and then hung in a chamber where the fumes of hydrogen sulphide gas, made by the action of dilute sulphuric acid on ferrous sulphide, can act upon the silver nitrate and thus change it to the black, metallic looking silver sulphide. The specimen is then hung up to dry, which should take about a half hour.

For electroplating on top of the silver sulphide film, the regular sulphate of copper plating bath is used. This bath is made up by dissolving enough copper sulphate in water to make the hydrometer reading about 16 degrees Beaumé, and then by adding enough sulphuric acid to bring up the hydrometer reading about two degrees more. The specimen is hung in this bath as cathode, with plates of copper as anodes, and the current is turned on. If properly prepared, the specimen will slowly become covered with metallic copper. The covering starts next to the copper wire which holds the specimen and spreads slowly out over the rest of the surface. The amount of current which is flowing through the solution should be regulated carefully so as not to obtain a brittle deposit.

After the deposit has become fairly heavy, which should be after from two to three hours, the specimen is taken out, thoroughly soaked in water, to remove the plating solution, and then heated to a red heat in order to carbonize the organic matter inside, and to anneal the copper and make it less brittle. The carbon may be broken up by inserting a wire through a small opening in the copper shell, and should then be shaken out.

The surface of the copper may be cleaned by being dipped in nitric acid. It may then be further electroplated with silver, gold, or any desired metal, and should be lacquered to preserve this finish.

EXPOSITIONS OF PROCESSES

SUGGESTIONS ON THE STUDY OF MATHEMATICS[1]

[The following little article was included in the chapter on process-exposition because the main part of it contains suggestions for the successful carrying out of an intellectual process, the solution of a mathematical problem, and it is expected to furnish "priming" for a theme on *My Method of Working a Problem*, *How to Prepare a Laboratory Report*, or some similar subject which requires a basic chronological plan. On the rhetorical side the little exposition may be studied for its division and arrangement of material. It should be compared with *Student Theme* No. 5 of Chapter VIII (p. 272), which, it will be observed, is not an exposition of a process.]

It is obviously impracticable to lay down specific directions that will adequately guide the student in the study of any science; nevertheless, it is hoped that the following general suggestions may be of service, and assist the student early in his course to acquire habits of work essential to success in the study of mathematics and of the other exact sciences.

Successful intellectual work depends very largely upon *the power of concentration*. Fortunately this power can be acquired and cultivated. The student must study away from interruption and then must not permit his work to become interrupted by himself or by others. By holding his attention upon his work and by keeping his mind from wandering to extraneous matters, the student will cultivate a fundamental habit that will tend to assure his success both in and out of college.

In a course in mathematics a student (1) *studies a textbook* and

[1] Issued to students by the Department of Mathematics, University of Wisconsin. Reprinted by permission of Professor Charles S. Slichter, Chairman of the Department.

(2) *works exercises and problems.* An assignment for a given day may therefore consist of the study of mathematical principles and theory (such as theorems, definitions, and explanations of processes) or it may consist of the working out of exercises and problems, or, as is usually the case, it may consist of the theory and principles of processes, together with an assignment of exercises illustrative of the theory.

1. The Study of the Textbook

Studying a mathematical textbook involves much more than the *mere reading* of the statements of principles and of the explanation of processes. The student must usually read the assigned paragraphs several times and must frequently turn back and re-read portions of the text included in previous lessons. In this manner the various points in the reasoning or explanations can be thought over, and *the habit of asking self-put questions about the work can be acquired.* This habit is what constitutes "the scientific method of study." It is the proper method in all departments of pure and technical science.

First of all, in preparing a lesson, try to find out what it is about—what its purpose is. Try to decide how you yourself would go about the accomplishment of the task and, if possible, *make an independent attempt of your own.* The more consideration you give to such an attempt, the greater scientific power you will gain.

In particular:

(A) The student should remember that the words in science have exact meanings and, of course, these meanings must be known to the student. In studying mathematics the student should acquire and use the language of mathematics. For example, he should not say "equation" when he means "expression." Indeed, he should go farther than this. He should make a conscious effort to use absolutely correct English, not only in written work but in oral work as well.

(B) While studying the text, work out theorems or illustrative examples with pen and ink. Do not rely upon a mere reading—even repeated readings—of a new piece of reasoning or of the explanation of a new process.

(C) *Read over all of the lesson assigned in the text a last time after* *working the assigned exercises.* The text will probably have a new meaning after working out the special cases in the exercises. This habit will give a meaning to the words, "Learn by doing."

(D) Finally, make a mental summary of each lesson.

(E) Review often.

2. The Working of Exercises

(F) Read each exercise or problem carefully and *plan a method of attack in advance* in order to facilitate arrangements of equations and computations and the drawing of figures.

(G) Look at your result and see if it is a reasonable one.

(H) Check result.

(I) Indicate the results by a distinguishing mark or summarize in logical order.

(J) The figures and diagrams should have sufficient lettering, titles, etc., to make them self-explanatory. The units of measure used should, of course, be clearly indicated.

(K) Do all work neatly the first time and (except drawings) *invariably in ink.* Try to have the first draft sufficiently neat in appearance and arrangement to hand in to your instructor.

(L) After the first draft has been finished, read it over carefully to see where it may be improved in method or arrangement and *think* about the processes you have used. If small changes only are needed to effect the desired improvement, make them by drawing lines through the portions to be changed and by making neat insertions. If considerable changes are necessary, do the work over.

The study and improvement of the work will prove to be of fully as much importance to you as the doing of the work itself.

(M) See to it that each piece of work or exercise is *complete.* On any piece of written work *the nature of the problem should be clearly and briefly stated.* The student should learn to think of each piece of work as a thing that is in itself worth while. Hence each detail should be attended to before the work is submitted to the instructor. See that sufficient explanation is given and that the numbers and magnitudes are adequately named and labelled.

(N) Hand in work at the time it is due.

3. Orderliness, System, Neatness, and the Rating or Marking of Work

The student may come to the University with the notion that the only thing desirable in mathematics is accuracy of numerical results. To correct such a notion and to offer every possible inducement toward neatness and attractiveness of work:

(O) The department offers a maximum of eighty-five points out of the possible one hundred on the basis of excellence of method and accuracy of result. The remaining fifteen are given on the basis of neatness, accuracy of spelling, choice of English, and general appearance of the work. The instructor reserves the right to refuse to consider any piece of work that is not attractive in appearance.

4. Specific Directions

The formal or merely mechanical requirements of good scientific work are important—in fact, the importance of these requirements can hardly be overemphasized, on account of the very general neglect of them in the early training of many of the students entering American colleges and universities.

The instruments and materials needed for mathematical work are outlined in the introduction to Elementary Mathematical Analysis (pp. xi, xii) and need not be repeated here.

(P) All mathematical work should be done on one side of standard size letter paper, $8\frac{1}{2} \times 11$ inches. This is the smallest sheet that permits of proper arrangement of mathematical work. The paper should be punched for preservation in notebook cover. The left side of the top of each sheet should bear a description of the work, or references to the pages of the text, and the right side of the top of each sheet should bear the student's name. A special form of paper pad has been prepared for general mathematical work. It is known as "Calculation sheet, Form M2," and it should in general be used.

(Q) Have assigned exercises in readiness (in folder) to hand in to instructor every day.

(R) Keep in a loose leaf notebook or in a folder all exercises returned by your instructor and all other exercises solved, in order that you may have them for review and may be able to show them at the end of the semester if they are called for.

(S) Full credit will not be given for work that is handed in later than the day on which it is due.

5. Corrections

The student should keep these suggestions for reference. Remarks concerning the student's written work will often be made by reference to the lettered paragraphs of this leaflet; thus if a piece of work bears the letter (G) it means that the result is an unreasonable one; (M) means that the nature of the problem is not stated, or that sufficient explanation is not given, or that numbers and magnitudes are not adequately named and labelled, etc.

Erecting a Tent[1]

Herbert M. Wilson

Geographer, United States Geological Survey

[Not all process-expositions deal with manufacturing processes. Many are explanations of abstract processes, like the exposition of a method of solving a problem in mathematics, and many explain how things are accomplished, rather than made. To this last class belongs the following simple explanation of how a tent should be erected, ditched, and floored. Such explanations quite frequently take the form of directions, which differ from simple explanations only in the more direct attitude of instruction which characterizes them, with the imperative mode of the verb replacing the indicative and the entire tone becoming definitely didactic.]

361. Erecting the Tent.—To properly set up a tent it should be taken by the ridge and dragged away until laid out flat. The ridge-poles should be inserted through the ventilation-holes, the supporting poles inserted in the ridge-pole, and the whole raised and

[1] Pages 825–827 of *Topographic Surveying* (John Wiley and Sons, 1902). Reprinted by permission of the author and the publishers.

the corners at once guyed out. The corner ropes by which the tent is first stretched should be drawn in a diagonal direction so as to make an angle of about 45° with the walls. The door should be tied up so that the tent may be given its proper shape, and the wall-corner loops pegged down and door fastened to hold the whole in place. Then the side ropes should be guyed out and the tent stretched taut by tightening a little on each rope at a time.

The fly must be laid over the tent when on the ground, and be raised with it. Then it must be so stretched as to touch the tent at no point excepting at the ridge, while at the eaves it should be from 6 to 10 inches above the roof of the tent. (Fig. 187.) This result can be obtained by several methods. One is to use pegs with two notches, on the lower of which the tent-guys are fastened, and on the upper the fly-guys; or an additional row of pegs may be set a foot beyond the tent-pegs for the support of the fly-guys. Where much rain or heat is encountered, short crotched poles about 10 inches longer than the height of the wall should be cut and one of these be set under each of the corner fly-guys to raise the fly away from the tent roof. As a protection in high winds long guys should be stretched from each end of the ridge-pole in front and rear; otherwise storms blowing end on may carry the tent away.

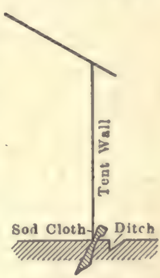


FIG. 192.—Sod-cloth and Ditch.

362. TENT DITCHING AND FLOORING.—Where the ground is moist or rains are to be provided against, the tent must be ditched in order that the water shall not run under it and wet the soil inside the tent; and where the camp is to remain in the same place for some time, the comfort of the party will be greatly increased by adding a floor to the tent. To *ditch a tent* a sharp spade or mattock should be used, and the soil be cut squarely or vertically just outside the foot of the wall (Fig. 192). The soil should be pitched away and an easy slope left on the outside of the spade-cut. Dirt should never be banked up against the outer wall of the tent, as it rapidly rots and destroys the canvas. The ditch should be cut sufficiently deep to assure its carrying off any ordinary rainfall, and should be made deep or shallow in various parts according to the slope of the ground, so that its bottom may have a uniform slope towards the lowest ground. At such point the ditch should be

carried away from the tent a short distance in order to assure egress of the water from the ditch.

The comfort of the occupants of the tent is increased by using a small strip of canvas or similar material as a floor on which to stand in dressing. Still better is a *canvas floor* of the full size of the interior of the tent, and this can rest upon the sod-cloth to keep out the wind. Where facilities for transportation permit, a *wooden floor* of tongue-and-grooved planks the length of the tent—say 9 feet—and fastened together by cleats in sections of 3 feet width may be provided. These 3 × 9-foot sectional floors can be easily handled in moving, and the whole tent can be floored with them or only one or more sections be placed in the space between two cots.

A still *more substantial floor* for a permanent *winter camp* consists in laying 2 × 4 scantling as floor-joists and planking these over so as to make a full floor which shall extend outside the canvas walls. The rain will run under this, and a little carpet or canvas on it will keep the wind out. At each corner a 2 × 4 joist should be erected the height of the wall and these corner posts should be connected by smaller scantling so as to form a railing the height of the wall. Over this the tent will be stretched, the framing of scantling holding it out in shape. It is unnecessary except in very high winds to guy out tents stretched in this manner, the guys to the fly being sufficient protection.

SUBMARINE CONSTRUCTION[1]

CHARLES W. DOMVILLE-FIFE

[A series of simple explanations of different processes employed in submarine construction of various types. In a study of the article the following should be noted: (1) the introductory indication of the place of the chapter in the plan of the book, (2) the undertone of big accomplishment and the suggestion by the frequent use of "we" of a "personally conducted" explanation, which

[1] Chapter XIII of *Submarine Engineering of To-day* (J. B. Lippincott Company, Philadelphia, and Seeley, Service and Co., Ltd., London, 1914). Reprinted by permission of the J. B. Lippincott Company.

flavor the exposition to the taste of the general reader, (3) the employment of frequent simple analogies, and (4) the use of diagrams to assist in the explanation. An illustration showing the interior of an air-lock diving bell has been omitted in reprinting.]

The work of the submarine engineer may be divided into three sections, each of which is really a science in itself and has its own professors or specialists. The first is covered by the word "salvage," which has already been dealt with; the second is "construction," the subject of this and the succeeding chapter; and the third section is "demolition," which will be dealt with later. There are, of course, numberless other "jobs" which the submarine engineer and his right-hand man, the diver, are called upon to do, such as the work performed on shipboard and in wells and mines, but these may be reckoned as subsidiary to the three great divisions of the submarine branch of engineering science. During recent years, however, a fourth, and even more important branch, has been added to the already heavy and difficult task of the engineer; this is submarine boat construction, about which, however, more anon.

Before going further, let us pause for a moment to consider the vast amount of submarine construction now undertaken, and its diverse character. Foremost comes the building of harbours, docks, and breakwaters; stupendous works which the organised effort and skill of several thousand men can seldom erect within two or three years. The Libau Harbour works (Port Alexander III), Russia, affords a brilliant example of the gigantic nature of such works. The main pier of this harbour is a mile and a quarter in length, and its breadth is 36 feet at the bottom and 24 feet at the top. It is constructed throughout of concrete blocks, weighing from 25 to 30 tons; and the depth of water at the pier-head exceeds 35 feet. The protecting breakwater, which is three and a half miles in length, has six heads, making three harbour entrances, and each head is composed of 300 concrete blocks. These works enclose five square miles of water, and in the pier itself there are no less than 15,753 immense blocks of concrete. All this is, of course, in addition to the temporary staging and piers required for the purposes of construction.

One British diver, Mr. James Murphy, and an assistant, sent out by Messrs. Siebe, Gorman and Co., trained for under-water work thirty-seven Russian masons, and, notwithstanding the rigorous winter climate, the whole of this gigantic work was completed in three years and nine months.

In order to realise the number of these huge harbours, and the almost incessant demand for the extension and improvement of the shipping accommodation afforded, we have only to consider for a moment the ocean-girt British Empire, with its almost countless ports of call in all quarters of the globe, and the thousands of miles of harbour-dotted coastline of the two Americas, to arrive at a

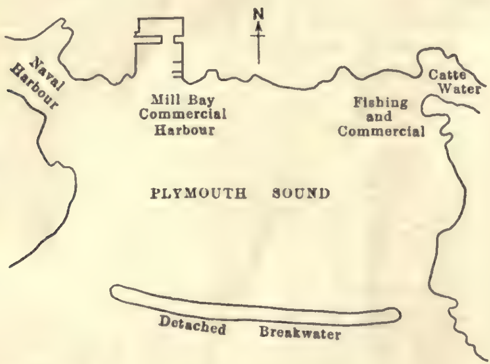


FIG. 29.—Plymouth Sound. Showing the system of protecting a deep water inlet by a detached breakwater. A natural harbour of the first class.

full understanding of the vital importance to the community of this branch of submarine engineering.

The form in which a harbour is constructed depends so much upon the configuration of the coast, the tides, and prevailing winds, as well as the purposes for which it was intended (naval, mercantile, or fishing), that no general rules can possibly be laid down. A natural harbour, that is to say a sheet of deep water, well-sheltered by surrounding land and unaffected by abnormally strong currents and winds, with an adequate entrance not blocked by immovable sand-banks or rocks, such as Plymouth Sound, naturally takes much less artificial work to make it safe and convenient for shipping than does a more open position. Likewise the mouth of a broad and deep river is more easily converted into a well-protected harbour entrance than a mere indentation of the coast line.

The usual method employed in protecting the entrance to a harbour is to screen it from strong currents and heavy seas by concrete piers and breakwaters. The accompanying diagrams will make clear the broad outline of the principles involved.

When the sea-bed of the proposed harbour site has been carefully surveyed by divers, the nature and direction of the piers and break-

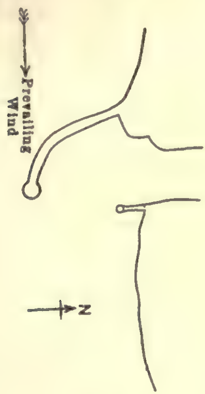


FIG. 30.

FIG. 31.

FIG. 30.—A protected river mouth.

FIG. 31.—Colombo (Ceylon). A semi-artificial harbour formed by the construction of three breakwaters and aided by the configuration of the coastline.

waters is decided upon. First of all, after the plans have been drawn, light temporary piers are erected. For this purpose screw-piles are often employed to support the staging. These are the long iron columns, with a large screw-thread on the bottom end, so frequently used to support seaside piers. They are put down into the sea-bed and screwed round, and so driven deep into the ground just as a screw is driven into a piece of wood. In some cases, however, the ordinary pile, a metal or wood column with a pointed end, is used. When this is the case, instead of being *screwed* into the sea-bed they are hammered in like an ordinary nail into wood.

Many of my readers will, doubtless, be familiar with the working of a *pile-driver*, having perhaps seen it in operation at one of the seaside resorts, where the wooden piles of the groynes used to prevent the loss of sand and shingle caused by the tide, the wind, and the waves, are almost constantly being replaced by the aid of the huge hammer. It consists of a vertical wooden frame, up and down which slides a heavy block of iron, called a monkey. This weight is hoisted to the top of the frame by means of ropes attached to a winch; when near the summit, a catch automatically releases

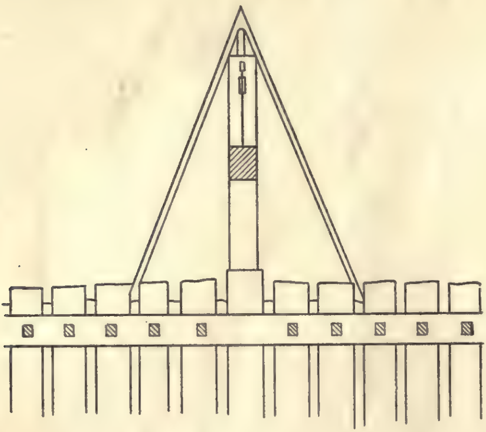


FIG. 32.—A Pile-driver. The metal block or "monkey" is shown shaded. When it has been hauled to the top of the guide it is automatically released, and falls on to the head of the pile.

the weight from the ropes which are hoisting it, and the arrangement is such that it falls upon the head of the pile, driving it into the sea-bed with an action analogous to that of a hammer (see Fig. 32).

The temporary staging usually consists of a roughly constructed pier, up and down which railway tracks are laid so that the trolleys and travelling-cranes handling the huge concrete blocks can move with quickness and safety. When this has been built, the work of levelling the sea-bed, so that the foundations of the concrete pier or breakwater may be solid, commences in earnest. This is mostly carried out with the aid of diving-bells and pneumatic tools. As this portion of the operations has already been dealt with in previous chapters (see pp. 116–137) no further description is necessary.

Next comes the herculean task of making the large number of immense concrete blocks required for the actual construction of the permanent piers and breakwaters. Concrete, which is formed by mixing stones, either whole or crushed, with sand and Portland cement in suitable proportions, is a material which is being used more and more every day for purposes of construction. When it is being used for large harbour works, the blocks are mostly "made on the premises." There are several different ways of mixing con-

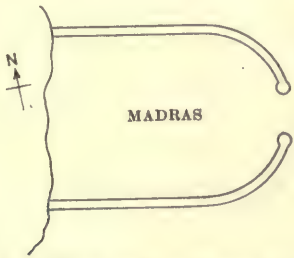


FIG. 33.—Madras. An artificial harbour on an exposed coast-line, formed by the construction of two breakwaters, converging at their outer ends.

crete and forming it into blocks on a large scale, but the essential features of all are the same, the difference being only in the actual method of work. Here I shall describe the concrete-making arrangements employed at the Gibralter Dockyard Extension Works, which cost Great Britain several millions sterling.

A network of narrow-gauge railway lines were first laid down to facilitate the conveyance of the various ingredients to and from the works. At one end huge crushers broke up the stone brought in by the railway from the quarries. The trucks were made to run up an incline to the top of the machines. The stone was then tipped into the crushers, to emerge a few minutes later, crushed to the requisite degree of fineness, through a shoot into more trucks waiting for it below. When sufficient of these were filled, they were coupled-up into a train and drawn away to the block-making works.

The process employed for making the concrete blocks is most interesting. On an elevated platform stood heaps, which were constantly being replenished, of all the necessary ingredients—cement, sand, and crushed stone. At regular intervals along this platform were conical-shaped holes or bins into which an army of workmen shovelled the proper proportion of each ingredient. When filled, a signal was made to a man under the platform, who promptly released the bottom of the bin, and the mass fell through by its own weight into a *mixer* placed directly underneath. The mixers consisted of boxes which were made to revolve eccentrically on two pivots. Water was then added, and the boxes revolved for a certain time to mix thoroughly the contents. When this had been done the boxes were opened over tip-trucks waiting below, and the muddy looking mixture slid into them. The trucks were then run off along one of the lines of rails to the block-making moulds, which covered acres of ground. These were merely wooden cases, which formed the wet concrete into square blocks and held them until dry and hard.

In order to show the capacity of big concrete-making works, which, it must be borne in mind, are merely temporary arrangements lasting only so long as the work of construction continues, it is sufficient to point out that at McCall Ferry, Pennsylvania, where a huge concrete dam has recently been thrown across the Susquehanna river, the works were capable of turning out 4000 tons of concrete a day, and that 20,000 tons of material was kept in stock.

We now arrive at the actual constructive stage in the building of harbour-piers and breakwaters. The temporary staging, erected over where the permanent pier is to be built, has already been run out from the shore, and on its deck railway tracks have been laid so that the train-loads of concrete blocks can be moved out over the water as the work proceeds. The supply of concrete blocks is sufficient to commence, and the sea-bed has been levelled and prepared by divers and workmen in diving-bells. There are, however, two other important pieces of mechanism which have not yet received attention—the *titan* and *goliath* cranes. These powerful appliances are used for lifting the concrete blocks from the trucks and lowering them into their places under water.

The drivers of these cranes, which are all worked and moved backwards and forwards along the tracks by steam, are in constant telephonic communication with the divers adjusting and fixing the concrete blocks under water, and also with the workmen levelling the sea-bed from the diving-bells. It will therefore be seen that the precise moment and position for lowering the blocks is determined over the telephone wires from the divers waiting below to guide them into their places.

These huge concrete blocks, often weighing 50 tons each, are built up into the wall just like ordinary bricks. Sometimes they are held in position by iron staples embedded in the concrete and made to dovetail together, and at others merely by cement. The shape of the wall, which is built in tiers, depends upon the power of the wind and sea which it will have to withstand. The most usual form, however, is shown in Fig. 34. The broad base gives additional strength, and the curved outer facing tends to throw off the spray when the waves beat against them. Inside the harbour

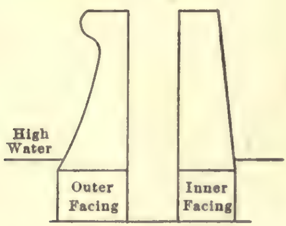


FIG. 34.—Section of a breakwater or sea-wall, showing the curved outer facing.

the walls forming the actual quays become almost perpendicular so that vessels can lay close alongside, while the face of breakwaters exposed to exceptionally heavy or searching seas is often given a much greater slant in order that the enormous force of the breakers may not be exerted at the moment of impact, as would be the case with a wall perpendicular or nearly so, but expended more gradually on the concrete incline. For the purpose of sea-defence, however, granite blocks are often used instead of concrete for the facings of the wall on account of their greater strength, but where the work is an extensive one the additional cost is frequently prohibitive, and resort is had to "ferro-concrete," which is nothing more than the ordinary concrete "reinforced" by having a network of iron rods embedded to hold it together.

THE FOUNDATIONS OF BRIDGES

One of the most difficult parts of a bridge to construct is undoubtedly the foundations, and it is exactly this part, and this part only, which falls to the lot of the submarine engineer. Let us confine our attentions, therefore, to the laying of these foundations by the methods most frequently adopted.

Much depends upon the depth of water and the nature of the river-bed. It frequently happens that not only is the water deep, but many feet of loose mud and clay cover the harder and more solid stratum on which the actual foundations of the bridge must rest. To get down on to the river-bed and clear this away is therefore the chief difficulty to be faced. Recourse is usually had to a

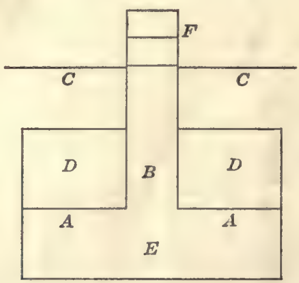


FIG. 35.—Large bridge caisson and airlock. (Description in text.)

"caisson," or large iron box, inside which, when sunk on to the river-bed, work can be carried on, and which will itself eventually form a portion of the foundations. The use here of a diagram will simplify the task of describing the construction of a caisson, and the manner in which it is used in conjunction with an air-lock.

The caisson is built of steel plates riveted together, and half-way down the interior is a steel floor (*A*), from which an air-tight shaft (*B*) leads up to the surface of the water (*C*). The two chambers (*D*) are filled with concrete in order to make the caisson sink as deep as possible into the mud of the river-bed by its own weight; but the large working chamber (*E*) is open at its lower end, and has a sharp edge all round to enable it to cut into the mud and clay.

The air-lock (F), which is fitted by an air-tight joint to the top of the caisson shaft, has been described in an earlier chapter.

The *modus operandi* is simple. The whole caisson is lowered on to the river-bed, and the edge of the bottom or working chamber immediately cuts into the soft mud or clay to a depth of several feet. When it has settled down as far as it will go of its own weight, which by the way is very considerable owing to the concrete already filling the two upper chambers, air is pumped in through the shaft, and the water is thus prevented from entering the working chamber of the caisson.

The air-lock at the top of the shaft enables men and buckets of dirt to be passed up from the working chamber, resting on the river-bed, to the temporary staging above the surface without allowing any air to escape. It will easily be seen that if this arrangement of air-tight doors was not made, the moment the air-pressure in the caisson was released by men getting in or out, the water would rush up and fill the working chamber.

When the caisson has settled down as far as it will go into the bed of the river, men descend through the air-lock into the working chamber, and commence removing the mud and clay from the inside. As this work proceeds, the caisson gradually sinks deeper and deeper, until its edge reaches a hard stratum capable of forming a solid and lasting foundation.

When this has been accomplished, the whole interior of the working chamber and the shaft leading to the surface is filled up with concrete, thus forming a huge concrete block in a steel casing. But the work does not always end here, for the shaft—which, however, is no longer a shaft, but has become a column of concrete and steel—is encased with stone blocks built up on the roof of the caisson, thus forming the enormously strong stone piers with a steel and concrete core which we see supporting so many bridges.

Among other submarine constructive works must be mentioned the laying of sewerage outfall pipes in the sea, and electric cables, gas and water mains on the beds of rivers. Although, compared with the building of harbours, breakwaters, piers and bridges, they are but insignificant undertakings, their importance and utility to almost everyone cannot be denied.

Many readers will have noticed when walking along the seashore at low tide in the vicinity of towns, large iron pipes, supported by wooden trestles well embedded in the sand or shingle, running down the foreshore and disappearing into the sea. Sometimes the pipes are embedded in concrete, but more often than not they are left bare and merely held in position by stout wooden piles driven into the sea-bed. These, then, are outfall pipes which carry the sewerage some distance into the sea, only releasing it when the tide is ebbing so that it may be carried out and distributed by the currents of the ocean.

Few people realise, however, that the laying of these pipes, joining them together, and securing them in position, is often a task of considerable difficulty. In some places quicksands have to be spanned and in other rocks levelled in order that these pipes may be run out at the correct angle at the most convenient spot some little distance from the sea-front of the town which they serve. If, for instance, the set of the tide comes from the south-west, as it does on many parts of the south coast of England, these pipes are generally laid so as to incline in the same direction. This is done with the primary object of making it easier for the sewerage to leave the pipes when the tide is ebbing.

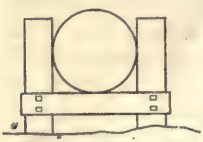


FIG. 36.—Sewerage pipe on trestle foundation.

The formation of the wooden piles or trestles on which these pipes rest is shown in Fig. 36, from which it will at once be seen that the pipes are prevented from sinking into the sand by the wooden cross-pieces, and from being moved to the right or left by the perpendicular piles driven deep into the sea-bed.

About the laying of electric cables, gas and water mains, on the beds of rivers little need be said, for the methods are very similar to those employed in sewerage outfall work. There are, however, many other "odd jobs" which come within the province of constructive submarine engineering, such as the laying and repairing of ships' moorings, cleaning and repairing sluice-valves and dock-gates, and sinking cylinders in wells, etc., but needless to say none of these has the same importance as pier, bridge, and harbour construction.

The Construction of a Large Reflecting Telescope[1]

George Ellery Hale

[A clear explanation of an unusual process. The elements to be noted particularly are the distinct division of material and the careful combining of the descriptive and the narrative parts. Several plates illustrating the article have been omitted in reprinting, but references to them in the text have been retained.]

The grinding and polishing of a 60-inch mirror involve a variety of operations, described in detail in Ritchey's memoir *On the Modern Reflecting Telescope and the Making and Testing of Optical Mirrors,** the most authoritative treatise on the subject. A brief account of these operations, taken in large part from the above source, may be of interest here.

It is first necessary to obtain a suitable disk of glass. The disk (of plate glass) made by the French Plate Glass Works, of St. Gobain, France, for the reflecting telescope of the Solar Observatory is 60 inches in diameter, 8 inches thick, and weighs a ton. It must be remembered that the requirements for a large mirror are very different from those for a lens through which light is to pass. The mirror disk is merely a support for the thin silver film on its front surface, from which the light is reflected without entering the glass. For this reason the great perfection of a lens disk is not necessary. Nevertheless, the glass must be free from striæ and other evidences of irregularity of structure. It should contain no large bubbles, though a few small ones, if they do not lie on the surface, are not objectionable. The most important condition, however, is freedom from strain caused by imperfect annealing. Evidences of strain are detected by a test with polarized light. Such a test, however, cannot be final, as an incident in the history of a great telescope objective illustrates. The disk had been carefully annealed and

[1]Chapter XXIII of *The Study of Stellar Evolution* (University of Chicago Press, 1908). Reprinted by permission of the publishers. Use of the article was suggested by Professor J. H. Atkinson, Iowa State College of Agriculture and Mechanic Arts.

* Published by the Smithsonian Institute. [Author's note.]

was supposed to be suitable for its purpose. During the process of grinding it flew to pieces, on account of internal strain, the serious nature of which had not been recognized in the test with polarized light.

It may not be obvious why the disk must be so thick, when its sole purpose is to support the thin film of silver on its accurately figured face. Great thickness, however, is absolutely essential, to diminish the effects of bending due to the weight of the glass and to temperature changes. The thickness of a mirror should not be less than one-eighth or one-seventh of the diameter. Even with such thickness a special support system is necessary to prevent flexure.

Glass is chosen in preference to other materials for telescope mirrors because of its uniformity of structure, comparative ease of working, and capacity for a high polish. Its lightness, when compared with such substances as speculum metal (formerly employed for telescope mirrors), is an important advantage. Furthermore, a surface of pure silver, first used by Foucault, reflects a much larger proportion of light than polished speculum metal.

The grinding-machine, designed and constructed by Ritchey for his work on the 60-inch mirror, is shown in Plate XCII. The glass disk rests on a heavy cast-iron turn-table, carried by a vertical steel shaft. Between the lower surface of the glass (ground flat) and the turn-table are two thicknesses of Brussels carpet, which form an admirable support during the grinding and polishing process. The edge of the glass is ground true by means of a rapidly rotating iron face-plate, held against the disk while the turn-table is slowly rotated. The cutting material is powdered carborundum carried down between the glass and the face-plate by a slow stream of water. After the edge-grinding is completed, the two faces of the glass are ground plane and parallel, before the process of making one of these surfaces concave is undertaken.

The grinding-tools employed for this work are circular plates of cast-iron, strongly ribbed on the back, and divided into a series of small squares on the grinding surface, by two sets of parallel grooves, planed at right angles to one another. The tool rests on the surface of the glass, though in Plate XCIII it is shown suspended from the lever arm, employed to swing the heavy tools into or out of position. During the grinding the disk is slowly rotated and the tool, also kept in rotation, is moved over its surface in a series of strokes from four to eight inches in length, by means of the arm shown above the disk in Plate XCIII. On its right-hand extremity this arm terminates in a steel shaft, which moves back and forth through a swiveled bearing supported on an adjustable slide. In this way the position of the grinding-tool on the disk can be changed laterally, so as to bring the stroke across the centre of the glass or near the edge. If it is found, for example, that the centre is being cut away too rapidly, the tool is moved near the edge and the grinding continued there until the error is corrected. The tool is not kept at any one position for a great length of time, to avoid producing low zones in the glass.

For the grinding process, various grades of carborundum are prepared in the following way: The powdered carborundum is mixed with water and thoroughly stirred. After settling for two minutes the coarse particles reach the bottom of the bucket and the liquid, containing "two-minute" carborundum and the finer grades, is siphoned off into another bucket. After the contents of the second bucket have been allowed to stand four minutes, the liquid is poured off and the "two-minute" carborundum at the bottom of the bucket is set aside for fine grinding purposes. In the same way, carborundum which has remained in suspension for periods up to one hundred and twenty minutes, or even longer, is prepared. These very fine grinding materials are used to give the smooth and almost polished surface obtained after the grinding with coarser carborundum is completed.

A perfectly true Brown & Sharpe steel straight-edge is used to determine whether the surface of the glass is approximately plane. When it is found to be sufficiently so for the preliminary work, the fine grinding is commenced, beginning with two-minute carborundum and continuing with finer grades. In this work the iron grinding-tool is counter-poised by placing weights on a lever arm connected by a shaft with the tool. The pressure is reduced from one-third pound to the square inch for the five- or ten-minute carborundum, to about one-twelfth pound per square inch for the one-hundred-and-twenty- and two-hundred-and-forty-minute carborundum. Unless this precaution is taken there is a great danger of scratching the glass.

After being fine ground, the back of the mirror is polished with rouge in the manner described later. No great pains are taken with this surface, although it is made very nearly plane, and is then polished so as to permit silvering (Plate XCIV). It is desirable to silver the back of the mirror, as well as the front, in order to prevent temperature changes from affecting the two surfaces in unequal degree.

The front surface, after it has been given a plane figure, is ready to be made concave. For this purpose a convex iron tool, of suitable curvature, is employed. In the case of the 60-inch mirror the radius of curvature is 50 feet. The curvature of the tool, and also of the glass, is tested from time to time by a spherometer. This consists of a tripod, with a micrometer screw at its center, which permits the deviation of the surface of a plane to be accurately determined. After the desired curvature has been secured, the fine grinding is carried to a point where the surface is very smooth and ready for polishing.

The polishing and figuring are done by means of a tool built up of narrow strips of wood, saturated with paraffine to prevent change of figure. The face of this tool is covered with squares of rosin, of a certain degree of hardness, which can be determined only by experience. The rosin squares are finally coated with a thin layer of beeswax, which forms the polishing surface. The soft wax is very useful, since small hard particles that may happen to be present in the polishing material are likely to bed themselves in it, thus reducing the danger of scratches. As a preliminary to polishing, the tool is placed in contact with the glass disk and pressed against it, by weights placed on the back, so that it may acquire the same curvature as the surface. After pressing for some hours, until the wax squares appear smooth and bright in all parts, the polishing may begin. This is accomplished by moving the tool over the rotating glass, by the main arm of the machine, as in the case of the grinding process. The polishing material is powdered jewelers' rouge, used commercially for polishing plate glass. The fine rouge is separated from impurities and coarser particles by a washing process similar to that used for carborundum. The rouge, mixed with distilled water, is applied to the surface of the glass by means of a wide brush of cheese-cloth.

The greatest precautions must be taken throughout the polishing process to avoid scratches. For this purpose the room in which the work is done is fitted up in such a way as to eliminate danger from dust. In the polishing-rooms of the Solar Observatory optical shops (Plate XCV) the plastered walls and ceilings are heavily varnished, and a canvas screen is hung above the glass, to protect it from any falling particles. The cement floor is painted, and kept wet when the polishing is in progress. The windows are double and carefully sealed, outer air being admitted to the room through a cheese-cloth filter. The temperature is maintained constant, within two or three degrees, by means of a hot-water furnace, controlled by a thermostat. The motor, driving-shaft, and apparatus for varying the speed of the grinding-machine, are carefully inclosed, only the slow-moving belt coming out into the room. No one is permitted to enter the room except the optician, who wears a surgeon's gown and cap. By observing such precautions the work may be continued for months without producing even microscopic scratches in the glass surface.

We may now assume that the glass has been polished, after receiving an approximately spherical surface. It then becomes necessary to apply a more accurate test than the spherometer permits. For this purpose the glass is turned into a nearly vertical position, where it is supported by a steel edge-band (Plate XCV). An artificial star, consisting of a hole about 1/300 of an inch in diameter illuminated by an acetylene lamp or other brilliant source of light, is placed at the centre of curvature, 50 feet from the glass surface. The light from the artificial star then falls upon the disk and is reflected back so as to form an image close beside the pin-hole. If the surface is perfectly spherical, it will appear, when examined by the eye placed at this point, to be brilliantly and uniformly illuminated. With an eye-piece, the image of the pin-hole will then be perfectly sharp, showing the most minute details or irregularities of the hole itself.

It is much more probable, however, that the surface will have many zonal errors. To detect and interpret these, the "knife-edge test," due to Foucault, is employed. If all the zones come to a focus at the same point, and a knife edge is moved across this point, while looking at the glass, the light will be cut off instantly from all parts of the disk. If, however, the curvature of certain zones is greater or less than the average curvature, these zones will resemble projecting or receding rings on an otherwise uniformly bright surface. The effect is as though the light were shining from one side, producing an appearance of relief by lights and shadows. The test is so sensitive that an error of 1/500000 part of an inch can be detected. If, for example, the finger is placed for a few moments on the glass, the heating of the surface will cause a swelling easily to be detected by the knife-edge test.

The process of figuring consists in removing the high and low zones by means of the polishing tool, the stroke and position of which must be modified in accordance with the results of the knife-edge test. After a perfectly spherical form has been obtained in this way, the difficult process of changing the spherical to a paraboloidal surface is begun. As is well known, the parallel rays from a star, falling on a spherical surface, will not be brought to a focus at a central point, but in an irregular figure, called a "caustic." A paraboloid, however, brings all parallel rays to a single focus, and produces a perfect stellar image. In the case of the 60-inch mirror, which has a focal length of 25 feet, the paraboloid is deeper than the sphere at the center of the disk by a quantity less than $\frac{2}{1000}$ of an inch. Months of figuring are required, however, to produce this small difference, because of the necessity of giving each zone of the paraboloid precisely the right curvature. In testing the surface from the center of curvature, the measured radius of each narrow zone of the mirror (the other parts being covered by a cardboard screen) must correspond with the calculated radius. The extreme difficulty of accomplishing this may be appreciated when it is remembered that the deviation of any zone from the surface of a perfect paraboloid must not be greater than $\frac{2}{1000000}$ of an inch which would correspond to a change of $\frac{1}{100}$ of an inch in the radius of curvature.

When parallel light is available, the difficulties of securing a perfectly satisfactory test of a paraboloidal mirror are greatly reduced. In this case the mirror, when seen from its focal plane (25 feet from the glass, or one-half the radius of curvature) appears like a uniformly illuminated plane surface when a perfectly paraboloidal form has been obtained. This method of testing with parallel light has been developed by Ritchey, and was used by him to secure the last degree of perfection in the figure of the 60-inch mirror.

As already explained the problem of mounting a large mirror is quite as serious as that of figuring it. It is necessary, in the first place, to support the mirror in such a way that it will retain its form, without bending, in any position of the telescope. Furthermore, it must be held so that it will not slip laterally, since the slightest change in the position of the mirror with respect to the tube will cause a displacement of the star images on the photographic plate. The mirror, thus supported, must be carried at the lower end of a tube, of skeleton construction, open at the top, and so mounted that it can be pointed toward any part of the heavens and made to follow the apparent motion of the stars by rotation about an axis parallel to the axis of the Earth. Strength and stability of the mounting, freedom from flexure, perfection of optical and mechanical construction and adjustment, and the greatest precision of driving—all these conditions must be met before a large reflector can be expected to give satisfactory results, in the more exacting departments of photographic work.

The difficulties thus presented have been most successfully solved by Ritchey, whose design for the mounting of the 60-inch mirror is shown in Plate XCVI. The telescope tube is hung beween the arms of a massive cast-iron fork, which is bolted to the upper end of the polar axis. This axis, a hollow forging of nickel steel, is inclined at an angle corresponding to the latitude of Mount Wilson (34° 13′) and thus rendered parallel to the axis of the earth Leveling screws, by which the base of the mounting is supported on its pier, permit this adjustment to be made with great precision. In order to relieve the great friction of this axis on the upper and lower bearings in which it lies, a hollow steel float, 10 feet in diameter, is bolted to its upper end, just below the fork. This float dips into a tank filled with mercury. Thus the entire instrument is floated by the mercury, and in this way the friction on the bearings is reduced to a minimum.

The 60-inch mirror rests at the lower end of the tube, on a support system consisting of a large number of weighted levers, which press against the back of the glass and distribute the load. A similar series of weighted levers around the circumference of the mirror provide the edge support. The path of the rays from the star may be as shown in Plate XCVII, Figs. 1, 2, 3, or 4. In the first arrangement (the Newtonian telescope), the parallel rays. after striking the mirror, are reflected back and would come to a focus at a point just beyond the end of the tube. They are intercepted, however, by a plane mirror of silvered glass, which turns them at right angles and forms the image on the photographic plate, which is mounted on the side of the tube near the upper end. In this case the focal length of the instrument is 25 feet, and the image is formed without secondary magnification.

If, however, it is desired to secure, for certain classes of work, the advantages of a greater focal length, a different arrangement is adopted. The upper section of the tube, bearing the plane mirror, is removed, and a shorter section substituted for it. This carries a hyperboloidal mirror, which returns the rays toward the center of the large mirror and causes them to converge less rapidly. They then meet a small plane mirror, supported at the middle of the tube near its lower end, which sends them to one of the following instruments, mounted in the focal plane: (1) a double-slide plate holder, carrying a sensitive plate, for the photography of the Moon, planets, bright nebulæ, etc., with an equivalent focal length of 100 feet (Fig. 3); (2) a spectrograph mounted in place of this photographic plate, in which case a convex mirror of different curvature is employed, and the equivalent focal length is 80 feet (Fig. 4); or finally (3) a third convex mirror may be used and the plane mirror inclined so as to form the star image (after sending the light down through the hollow polar axis) on the slit of a powerful spectrograph, of 13 feet focal length, mounted on a pier in a constant-temperature chamber (Fig. 2). In this case the equivalent focal length is 150 feet.

The telescope is moved in right ascension or declination by electric motors, controlled from the floor of the observing-room. The driving-clock moves the telescope in right ascension by means of a worm-gear, 10 feet in diameter, carried by the polar axis. The cutting of the teeth of this worm-gear is a mechanical operation requiring the highest precision of workmanship. Each tooth was spaced off by means of a finely divided circle attached to the polar axis, and read with a microscope. The rotating cutter was driven by an electric motor. After all the teeth had been cut, the worm and worm-gear were ground together for many hours, until all slight residual errors had been eliminated. The operation was completed with jewelers' rouge, which leaves a smooth and highly polished surface.

All of the heavy parts of this mounting were made, after Ritchey's designs, by the Union Iron Works Company, of San Francisco. They were then shipped to Pasadena, where the mounting has been erected in the Solar Observatory shop (Plate XCVIII). Here the worm-gear was cut, and all of the smaller parts, including the driving-clock, setting-circles, slow motions, motors, etc., are being fitted and adjusted. All of these parts were made in the Observatory instrument shop, which is equipped with the best machinery obtainable for work of this kind (Plate XCIX).

As soon as this mounting has been completed, the 60-inch mirror will be put in place and the telescope thoroughly tested, by actual photography of the heavens. It will then be necessary to transport the instrument to Mount Wilson—an operation of considerable difficulty, as several of the castings are very large, and weigh about five tons each.

The building for the 60-inch reflector is of steel construction throughout (Plate C). The thin inner walls will be shielded from the Sun by outer walls, and air will be permitted to circulate in the space between the two. The dome, 60 feet in diameter, will be rotated by an electric motor, either rapidly, when passing from one part of the heavens to another, or at a slow uniform rate, of such a speed as to keep the opening (15 feet wide) constantly opposite the end of the telescope tube, when it is following a star. The observer, when photographing in the principal focus, will stand on a platform suspended from the dome and rotating with it. The double-slide plate-carrier, with which stars and nebulæ will be photographed, is similar to that used with the Yerkes telescope (Plate XVII).

Refining Crude Petroleum[1]

Walter Sheldon Tower

[Professor Tower has succeeded admirably in doing a very difficult thing, in reducing a complex process to its essential stages. To appreciate fully the difficulties of keeping to the main channel in an exposition of an intricate process, the reader should know what is omitted as well as what is included; a careful analysis of the chapter can not, however, fail to reveal how unified and well balanced it is. The plan of the article, without being obtrusive, is distinctly evident. The following elements

[1] Chapter VII of *The Story of Oil* (D. Appleton and Company, 1909). Reprinted by permission of the publishers. The use of the selection was suggested by Grose's *Specimens of English Composition* (Scott, Foresman and Company).

should also be noted: (1) the skilful sketching in, early in the chapter, of the whole process, (2) the method of constructing the explanation of one step of the process upon the explanation of an earlier step, (3) the use of analogies and of concrete language generally, and (4) the smooth interweaving of divisions, even the introduction and the conclusion being linked neatly with the preceding and the following chapters respectively.]

The enormous supplies of petroleum in this country never had any great industrial value until some method of purification or refining was invented. The early attempts to use the crude oil for domestic lighting purposes in various places were invariably unsuccessful, on account of the sooty, smoking flame, and the extremely disagreeable, nauseous odor. Use as an illuminant was the only avenue of development which seemed to offer any real possibilities, but it was absolutely necessary that the quality of the oil should be improved by the removal of these objectionable features, if its use were to become general.

Purification of petroleum was done in a rough way many years before the modern process was perfected, but never on a very important scale. The medicinal oils used in European countries two centuries ago were generally subjected to some process of distillation or filtration. Refined illuminating oil from the Galician districts was introduced in the early part of the last century, and soon after that time filtering through charcoal was tried in this country to remove the odor and improve the general appearance of the crude oil. The first important refining plant in the world, however, was probably erected in the Baku district about 1823. It consisted of an iron still having a capacity of forty buckets, and said to give about sixteen buckets of so-called "white naphtha" from each charge. This refined oil found a ready sale at the great Russian fair at Nishni Novgorod, presumably to be used in lamps.

Petroleum refining in this country began in a small way about 1855, with Kier's experiments to turn his medicinal oil to some more valuable use. The manufacture of so-called "paraffin oils" from coal and shale had increased so rapidly in the decade following 1850 that there were some fifty or sixty establishments in the eastern part of the United States when Drake's well was opened. Kier's results had already shown clearly enough that paraffin oils could be secured more easily from petroleum than from coal or shale, and more cheaply also if the supply of petroleum were large enough. The prospect of securing petroleum in large quantities by following Drake's example made the entire shale oil industry totter. The owners of the refineries, many of which were then only fairly started, saw themselves facing ruin, until a simple and easy salvation appeared in converting their plants into petroleum refineries. Thus, the latter industry was able to profit immediately from the existence of this large number of ready-made establishments.

Kier's first attempts at refining petroleum had given him a "carbon oil" distillate, distinctly superior to the crude oil, but far from being perfect. The strong odor still persisted and brought a storm of complaints from the consumers. General dissatisfaction was expressed also on account of the rapidity with which the oil turned black, and on account of the formation of a hard crust on the wick which interfered with the free burning of the flame. As a result the "carbon oil" gained favor slowly, despite the fact that an army of canvassers and selling agents spread over the country to boom its use. Something had to be done to place petroleum oil on as satisfactory a basis as were the shale and coal oils. Distillation alone would evidently never suffice. Chemical treatment to purify the products after distillation was tried and soon demonstrated that successive manipulations with solutions of alkali and acid would remove the chief objectionable features. These improvements, already familiar abroad, had been introduced here about the time Drake went to the oil regions. Therefore, as soon as his well was struck, the refining of petroleum was in a condition to expand and drive the shale oil industry out of existence in short order.

The most important process in the refining of petroleum, as it is carried on to-day, consists essentially of two parts: first, heating the oil in a still until it vaporizes in the same way as boiling water passes into steam; and second, condensing these vapors just as steam condenses on cold objects. The successful separation of the different products depends on the fact that each of the many compounds composing crude oil has its own particular boiling point, and thus allows gradual heating to carry on the process of division, or fractional distillation, as it is called. The stills where the crude oil is heated, the condensers where the vapors of successive divisions are returned to the liquid form, and the tanks for storing the refined products, therefore, represent the important parts of the skeleton of every refinery.

The early refineries were mainly small plants with a few vertical iron stills resembling giant cheese boxes, and having a capacity of twenty-five to seventy-five barrels each. As the industry expanded, however, and made constantly increasing demands on the capacity of the refineries, larger and larger stills were introduced. A horizontal cylinder still was found to offer various advantages over the old cheese box style, and the cylinder form, with a capacity of about 600 barrels, is the type now generally used in this country.

Each still may have its own condenser, or several stills may be connected with a common condenser, although the former arrangement is preferable. In either case the condenser is the same, consisting of coils of three- or four-inch pipe several hundred feet long, and ordinarily kept cool by thousands of gallons of water pumped over them daily. The hot vapors entering the condenser from the still come in contact with the cold pipe and return to liquid form, in the same way as steam on a winter day will collect on the cold glass of a window and trickle down the pane in tiny streams of water. The refined product of a dozen condensers may be turned into a single receiving tank until the limit of its capacity is reached, and then other similar tanks are pressed into service.

Between the condenser and the receiving tanks, the distilled oil has to pass through the stillhouse and undergo the keen scrutiny of the stillman, on whose skill the success of the entire process depends. The condensed distillates make their entrance to the stillhouse through a V-shaped tube, such as are commonly inserted in drain pipes to prevent the passage of sewer gas, and which serves much the same purpose here. A vertical pipe on the condenser side of the V allows the uncondensable gases from the still, that is, those vapors which will condense only at very low temperature, either to escape into the air or to be led away to be burned under the still from which they came. The condensed distillate, now in the liquid form again, passes through the V tube and enters the stillhouse in what is called the separating box, a triangular, cast-iron affair. A glass door on one side of the box enables the stillman to watch both the color of the oil and the size of the stream as it enters the box. In this way, from the knowledge of long experience, he knows how to regulate his fires under the stills, and from occasional samples of the distillate he can determine when a different grade of oil has begun to vaporize in the still and is coming through the condenser. Shutting one valve and opening another close at hand turns the stream into a different receiving tank. So the process goes as long as separation is possible, or until some special requirements make it desirable to stop the distillation at a certain point.

The actual process of distillation consists in carefully separating the different hydrocarbon compounds which make up the crude petroleum. These "fractions," as the different compounds are called, are determined more or less arbitrarily by their weight as compared with an equal bulk of water, and by the ease with which they give off inflammable vapors.

Distillation may be done by what is known as the *intermittent process*, in which the major part of the operation is carried on in one still heated to successively higher temperatures by gradually increasing the fires beneath it. This method is most commonly used in the United States. Distillation may also be done by the *continuous process*, in which the crude oil is pumped through a series of stills, each succeeding one being heated to a constant temperature higher than that of the one preceding.

In the intermittent process, the crude oil in the still is subjected to a gradually increasing temperature, so that the different fractions pass off to the condenser in the order of their volatility. The lighter and more volatile compounds, that is, those boiling at low temperatures, are vaporized first, the heavy, less volatile compounds not appearing until the highest temperatures are reached. Different petroleums vary so widely in character, and the number of possible products is so large that each kind requires special treatment to secure the particular products for which it is best adapted. The distilling business, therefore, becomes decidedly intricate when examined in detail, and a high degree of skill must be exercised in manipulating the process so that it will yield the largest quantity and best quality of the valuable oils.

The general character of the treatment can be shown by comparing the two common processes known as "running to tar" and "running to cylinder stock." The main difference between these two processes is that the former gives the largest possible yield of illuminating oils and a small yield of heavier products for lubricating. The second process is intended to yield a maximum amount of the lubricating oils, with the illuminating oils of secondary consideration. In general therefore, one process is the direct reverse of the other in so far as its chief object in view is concerned.

Both processes start with crude oil heated in the still, and the vapors passing off into the condenser. The most volatile of these vapors begin to appear before much of any heat is applied to the still. They can be condensed only by special processes at temperatures near the freezing point, consequently in the ordinary course of distillation they pass off into the air through the escape pipe from the condenser or are led under the still to serve as fuel. The first distillate which condenses and passes through the V tube to the stillhouse is a clear, colorless light oil, but, as the process goes on, the stream of oil entering the separating box becomes heavier, and the color gradually changes through yellow to darker shades. The stillman tests the density of the oil from time to time, and on the basis of these tests and the color, he turns the streams into different tanks, by simply closing and opening convenient valves.

The stream passing through the separating box is continuous as long as the still contains any oil which can be vaporized, hence the stillman's divisions of the stream of distillates, or his "cuts," as they are called, are an exceedingly important part of the process. The first cut is usually made when oils of the naphtha class cease to appear. The second cut is the illuminating oil. In the "running to tar" process, the method known as "cracking" is employed after about two-thirds of the cut of illuminating oil has passed over, its object being to increase the proportion of illuminating oils obtained.

The exact changes which take place in the still during this "cracking" process are only partly understood. The process was discovered accidentally in 1861 by a stillman at Newark, N. J., who left his post one day after about half the contents had passed off, building a strong fire under the still to last until he returned, as he expected, a half hour later. Several hours elapsed, however, before he did return, and then, to his amazement, he found issuing from the condenser a lighter distillate than was being obtained when he left, whereas it should normally have been much heavier. Such an entirely unheard of thing led immediately to experiments, in which it was found that a portion of the heavy distillate, normally coming through the condenser last, had condensed on the cooler upper portion of the still, and dropping back on the highly heated liquid had encountered a temperature hot enough to cause decomposition of some sort, so that a lighter oil was the final result. Many different devices have been invented to aid in this cracking process, and, though some refineries use it but little, cracking has been of enormous benefit in the case of certain petroleums, naturally yielding only a small percentage of kerosene, yet rich in the grades heavier than kerosene, and not heavy enough to be high quality lubricating oils. By cracking, many of these intermediate grades are broken up, and become valuable illuminating oil.

After cracking has given as much kerosene as can be secured the fires are checked, and the tar process stops so far as the first still is concerned. A certain amount of thick residue, or "tar," always remains in the still and must be removed before the still can receive another charge of crude oil. This tar usually goes to a second still, where further distillation gives lubricating oils, paraffin wax, and coke. The cuts of naphtha and illuminating oils are also either redistilled or subjected to further treatment to purify them and separate them into different commercial grades.

The process known as "running to cylinder stock" is essentially the same as the other up to the point where cracking would begin, except that it is usually applied to crude oils naturally adapted to the manufacture of lubricants. The important difference consists in heating the still by free superheated steam within, as well as by the usual fire underneath the still. The presence of the steam causes a more even distribution of the heat, and more completely vaporizes the voltatile lighter oils from the whole charge without having to subject it to such a high temperature. When the distillate in this process appears too heavy for kerosene, instead of the cracking treatment, a third cut, known as the "wax slop," is often made. Different methods of handling the cut yield special brands of oil for a great variety of purposes, from the headlight oil of locomotives to the thin "spindle oils" used to lubricate light machinery. The entire elimination of the cracking process leaves a greater residue in the still after the "wax slop" cut is made and this residue, known as "cylinder stock," forms the basis for the manufacture of a host of lubricating oils.

The Russian process of continuous distillation differs from the American method only in using a series of a dozen or more stills, each of which is heated to a definite steady temperature. The crude oil passing from one still to another encounters these successively high temperatures, which correspond to the boiling points of the different petroleum products. Each still constantly gives off a distillate of uniform character, while the series of stills gives the same range of distillates as are obtained by the gradual application of increased heat in the intermittent system. The possibility of supplying the crude oil to the stills as fast as the distillates pass off results in important economies of time, less waste of fuel, and a minimum of injury to the plant by avoiding the cooling and reheating of the still. This process, however, is not well adapted to American conditions because of differences in the nature of the crude oils, and in the products most desired. The American refiner, in general, aims to produce as much kerosene or lubricating oils as possible, whereas in Russia the enormous demand for the residuum, or *astatki*, for fuel makes it nearly as valuable as any other product. There is, therefore, little inducement to increase the yield of kerosene and reduce the quantity of residuum by employing the cracking process, which can be done only in intermittent distillation.

The first distillates obtained from the crude oil by either process usually have to be redistilled or purified before they can be used. Any sulphur which is present must be removed either in the first process or subsequently. One method makes use of copper oxide in the first condenser, or in a specially constructed still, the sulphur by chemical union being removed in the form of a copper sulphide, from which the copper can be reclaimed and used over and over. Another method makes the separation by treating the distillates successively with sulphuric acid, caustic soda and litharge in agitator tanks built for the purpose, the removal in this case being in the form of a sulphide of lead. This treatment for sulphur is one of the most important and yet most troublesome processes of all, since the presence of a very small percentage of sulphur imparts a highly disagreeable odor to any distillate. No product can be sold until the last trace of sulphur has been removed.

The naphtha distillate, where obtained in important quantities, may be roughly separated into different grades, or cuts, known as gasoline, commercial naphtha, and benzine. When the division is made by the stillman, as they come from the condenser, washing with acid, water, caustic soda, and water again, in the metal agitators, to purify and deodorize is the only further treatment necessary before they are ready for shipment. More often, however, all the naphtha distillate goes into a single cut as it comes from the condenser, is subjected as a whole to the deodorizing and purifying treatment and is then redistilled and divided into the three fractions mentioned above. This redistillation of the naphtha is done in a special still heated by steam, and with the outlet, through which the vapors reach the condenser, rising for some distance before it actually enters the condenser coil. This arrangement is introduced to prevent any liquid from being carried over into the condenser with the gas. The condenser for the naphtha still also differs from the others in having two coils of pipe, the first of which has a "back trap," or pipe leading back to the still, so that any heavier oils present, condensing quickly, will be returned to the still. The main body of the naphtha distillate is condensed in the second coil of pipe, and is cut into standard grades by the usual separating-box method, but, in order to secure the very lightest of the products, it is necessary to use a third coil surrounded by a freezing mixture of salt and ice. The different cuts obtained from this distillation are immediately ready for use as soon as tested to prove their quality.

The distillate of illuminating oil, or kerosene, as we know it, if used just as it comes from the original still, has all the disadvantages which Kier's "carbon oil" presented, charring the wicks, giving off an unpleasant odor, and rapidly turning to a dark color after standing, all owing to the presence of various impurities. The illuminating "cut," therefore, is given the same sort of purification treatment as is applied to the naphtha. Testing and grading for sale then complete the last stages in the production of kerosene.

The manufacture of lubricating oils, and paraffin or wax complete the principal processes of refining. Some lubricating oils are produced by the processes known as sunning or reducing, depending on the evaporation of the lighter products either by exposing the crude oil in open tanks or by gently heating it with steam. This method of treatment is said to have originated from the observation that certain oils spilled on the streams of the oil regions were thickened by evaporation, and became fit for lubricating purposes without further treatment. Experiments with different oils showed the possibility of making natural lubricators in this way from special grades of crude petroleum. So-called "sunned oils" and "reduced oils" are still to be found on the market, but by far the greater proportion of machine oils are products of distillation.

These refined lubricating oils come either from the process of "running to cylinder stock," or from the redistillation of the "wax slop" and of the tar left in the still after cracking for kerosene is completed. These oils, in one way or another, form the basis of all grades of machine oil from the very lightest "spindle oil" to the heaviest grease. The processes of treatment differ only in minor details from those used for the lighter oils. Different cuts are made, and these cuts, together with varying methods of purification, bleaching and filtering, determine the particular grade produced. In general, however, the redistillation of the "wax slop" cut yields the major portion of the light and especially high-grade lubricating oils, while the heavier grades come from the cylinder stock.

Paraffin was once regarded merely as a by-product of distillation, but it is now so widely used in industrial processes that in some refineries it is fully as valuable as any of the other products. Paraffin is obtained from the redistillation of either the residuum left in the tar process after cracking is completed, or from the "wax slop" cut in the cylinder-stock process. In either case the paraffin distillation is carried on in heavy steel stills at very high temperatures. The paraffin passes off in one long stream of distillate, the latter end of which may be almost pure wax. It then undergoes the same chemical purification as the other products, the only difference being that the agitator must be heated to prevent cooling and solidification of the wax. The subsequent treatment, however, is much more complicated, consisting of a variety of steps as follows: to a settling tank where the water is removed; to a chilling tank where ammonia machines cause it to congeal and crystallize; to a filter press which forces out any oil remaining, and leaves only solid paraffin; to the melting tank to be converted into liquid paraffin again; to the bone-black filter where all color impurities are removed; and, finally, to the second chilling tank, where it is returned to the crystallized form ready for the hydraulic presses which convert it into cakes for shipment.

From this description it appears that only two of the important products of petroleum are regularly obtained directly from the first distillation; these are the illuminating oils and the cylinder stock, and both of these have to receive additional treatment subsequently. All other products are the result of a second distillation and of chemical manipulations. The percentage of the different products obtained by refining varies immensely, depending both on the original character of the crude oil and on the special aims of the individual refiner. Illuminating oils run as high as seventy-five per cent. or eighty per cent., and as low as twenty per cent. to twenty-five per cent. Lubricating oils vary from nothing up to twenty per cent., or thirty per cent., and the residuum and waste may be as high as thirty per cent. of the whole volume of crude oil. The residuum, representing the compounds which cannot be vaporized by ordinary means, is not, however, all loss, because, whether pitch, coke, or asphalt, according to the character of the crude oil, various methods of treatment and utilization are devised. Practically nothing is lost except moisture, solid impurities, and the varying amounts of uncondensed gases. Even the water used in washing the distillates is sent to huge settling tanks to recover any oil which may have been included in it.

The most volatile of these distilled oils, the naphthas, are extremely inflammable liquids, the gases from which make violently explosive combinations when mixed with air. The presence of a very small percentage of the lighter naphtha oils in illuminating or lubricating oils is, therefore, a constant source of danger. If such oils are used explosions and fires are sure to occur. . The danger is especially great in the case of naphthas present in kerosene, the most prolific cause of lamp accidents and fires in the early days of the industry. Continued complaints about the "deadly kerosene," as it was frequently called, led to the establishment of certain legal standards which all illuminating oils must meet. It has consequently become customary to subject all the distilled oils to standard tests in order to insure a uniform quality of the product. Testing is now fully as important a part of the refining process as is distillation itself, since it is the only safeguard for the interests of both producer and consumer.

The lighter oils of the naphtha group are usually tested for gravity, odor, and acid impurity. The gravity test is made with the usual Baumé hydrometer, and on the basis of this test the oils are graded for commercial purposes, as gasoline, naphtha, and benzine. The test for odors is made by simply saturating a cloth with the oil; as the oil evaporates from the cloth any foreign odors are readily detected. The presence of acid is revealed by testing with litmus paper, which immediately turns red if the acid has not been entirely removed. Benzines for special purposes, as in the manufacture of paints and varnishes, also have to be free from any of the heavier oils. The test in this case is made by soaking part of a sheet of paper in the benzine, if heavier oil, like kerosene, is present, a grease spot shows as the volatile benzine rapidly evaporates; otherwise the whole sheet of paper presents the same appearance.

The testing of kerosene oils is by far the most important of all, because the conditions under which it is used in ordinary lamps are especially favorable for the occurrence of explosions. Kerosene is tested for acid, sulphur, gravity, color, and what is known as the "fire test." Acid and gravity tests are the same as for naphthas. Color is, of course, determined by inspection, and furnishes the basis for division of the kerosene into the three grades common in this country: *water white*, which is colorless, and is the standard of American kerosene; *prime white*, of a faint yellow color; and *standard* or *standard white*, a pronounced yellow. In European countries other grades are recognized, as many as seven being commonly sold in Germany.

The fire tests, however, are the most significant since they determine the safe or unsafe character of the kerosene and the legality of its sale. Two fire tests may be used, one of them called the "flash test," determining the temperature at which the oil will give off an inflammable vapor when heated artificially, or when exposed naturally to the air. The other, known as the "burning test," determines the temperature at which the oil will take fire and burn on the surface. The latter temperature is usually from ten to forty degrees higher than the "flashing point," and, since the gravest dangers are from the generation of explosive vapors, the flash test means most.

A great number of devices have been invented for making the flash test, the essential principle of each being a closed or open cup in which the oil is heated. A common form of tester consists of a cup holding about the same amount of oil as a medium-sized lamp, the cup being immersed in water and heated carefully by heating the water, on the same principle as cooking in a double boiler. The glass cover of the cup has a hole for a thermometer and another for inserting a match to ignite the vapor. Kerosene, to be safe for lighting purposes, should have a flashing point higher than any temperature which it is likely to reach under ordinary conditions. In most places a flashing point of 110° or higher is required by law. Testing, however, usually begins as soon as the thermometer shows the oil to have a temperature or about 85° or 90°, and continues at intervals of every degree or two until the insertion of the match causes the appearance of a bluish flame in the cup. As soon as this "flash" flame appears the reading of the thermometer indicates whether the oil is up to the required standard. Illuminating oils for special purposes such as headlight oil for locomotives, signal lamps, miners' lamps, and so on, frequently have to meet much higher requirements than for ordinary domestic use, but the testing process is the same.

Lubricating oils are subjected to three important tests, viscosity, fire test, and cold test, each, in a way, being of vital significance in determining the value of the oil. The first, if any, is perhaps the most important since viscosity is the most necessary quality of any lubricating fluid. The test may be made in innumerable ways, but all depend on the principle of determining the length of time required for a given quantity of the oil to flow through a small opening. The temperature at which the test is made depends on the special use for which the individual oil is intended, ranging up as high as 212° in the case of cylinder oils for steam engines.

The fire test is necessary in the case of most machine and engine oils because the heat from friction might generate inflammable vapors if very volatile products were present. The cold test is also required to determine the temperature at which the oil would become thick and cloudy. This test is made by freezing the oil in a tube, and then as it melts, noting the temperature at which it begins to run. High-grade lubricating oils have to withstand a very wide range of temperatures; first quality cylinder oil, for example, must have a cold test as low as 55°, and it must not flash below 550° Fahrenheit.

All these tests must be made at the refinery, for each lot of distillates before they can be approved, graded, and loaded for shipment to the consumer. If any distillate does not "prove up," it has to go back for further manipulation to remedy the defects, the success or failure of the tests depending largely on the skill of the stillman in making his cuts as the distillate passes through his separating box.

In spite of its many steps and intricate processes there is nothing picturesque or spectacular in petroleum refining unless it is in the magnitude of the plant and the very obscurity of the many transformations going on everywhere yet entirely unseen. One refinery is essentially the same as every other save in size, and perhaps in a few minor details. At a hundred refineries from the Atlantic to the Pacific, and from the Lakes to the Gulf, the same story is repeated day after day and year after year, as the invisible stream of oil makes its journey step by step through the maze of pipes, stills, condensers, and agitators, leaving at every turn a part of its precious burden. On the one hand, the vast network of pipe lines binds the refinery to thousands of wells, scattered halfway across the continent. On the other hand, the world-distributing system carries the multitude of refined products into the daily life of every class of humanity.

CHAPTER VIII

EXPOSITION OF IDEAS

Principles

The composition of a technical description or of a process-exposition which really succeeds in its object of recreating in the mind of the reader a clear visualization of the object described or the process explained is by no means easy. But such expositions do not present, on the whole, as many difficulties as do expositions of ideas. The reasons for this fact are not hard to understand. Whatever the difficulties in technical description and process-exposition may be, the problem is always definite; the writer is dealing objectively with concrete facts, a visualization of which he is trying to create in the mind of the reader. In the exposition of ideas, on the other hand, the material with which he deals is fundamentally abstract, even where concrete elements may enter in; the writer aims, moreover, to create in the reader's mind not a mere visualization of things which can be seen, but an understanding of the immaterial and intangible. Furthermore, the writer of exposition of ideas usually meets a different attitude on the part of his reader from that which the writer of technical description and process-exposition meets. The reader of these latter types of exposition is usually merely receptive; the writer is only the medium through which things that the reader has not himself seen are brought to him. In most expositions of ideas, on the other hand, the writer is more than a mere recorder of what he has seen; he is also an interpreter and often the defender of a proposition; and the reader who was willing to accept without question the accuracy of what the writer *saw* may be quite unwilling to accept the soundness of what the same writer *believes*. In the first case, it is a question merely of trusting to the trained eye of an observer; in the second case, it is the much more delicate matter of placing complete confidence in his opinions and judgment. For these reasons, therefore, the writing of an exposition of ideas is more difficult than that of the simpler objective types of exposition.

The range of expositions of ideas is much greater than that of the other types of exposition. Under a classification based on the relation of writer and reader many are simple elucidations in which the writer is the teacher and the reader the pupil receptive to the ideas which he believes the writer capable of imparting. In this simple type the writer is merely a medium for conveying to another as clearly as possible a definite body of universally accepted truths. Such an exposition is the definition of *The Table of Single Potentials* (Student Theme, No. 4, p. 270). It is obvious that the task of the writer of such an explanation is a comparatively simple one since he does not have to be concerned with the soundness of the ideas which he is transferring. Most expositions of ideas are not, however, of this didactic type, but are based fundamentally upon propositions embodying the author's beliefs or opinions. Expositions of belief or opinion vary widely from demonstrations of propositions based on sound empirical evidence and widely accepted to those based on mere presumptive proofs and abstract reasoning, and accepted, in some cases, by the author alone. It is evident that the author's attitude toward the reader will vary from that of a demonstrator of hypotheses which the reader ought to accept to that of a supporter of beliefs which the reader might reasonably be unwilling to accept. Examples of expositions of belief or opinion will be found among the student themes which follow the text of this chapter. The definition of *The Chemical Engineer* (No. 6, p. 274), for example, is only an individual interpretation of the function of a chemical engineer with which we may or may not agree. Similarly, we need not accept the truth of the basic proposition of *The Value of Technical Journalistic Work to the Engineering Student* (No. 8, p. 276). Of the psychological basis of expositions of the first type mentioned, those which are merely elucidative, it need only be said that the writer should, of course, have a clear, sound understanding of the truths which it is his purpose to explain. Expositions of belief and opinion are more involved, and demand, therefore, a few suggestions concerning the logical matters of proposition building, evidence, and authority. Afterwards the problems of organizing the exposition of ideas will be considered.

It has already been said that expositions of belief or opinion consist essentially of propositions, expressed or implied, together with whatever the writer may have to say in support of them. Now the world is sometimes willing to accept a proposition without demanding the supporting evidence; but the world does so only because it either *wants* to believe the proposition or is willing to trust the authority of the maker of the proposition. In the latter case the reader assumes that the proposition is actually based on good evidence and waives his claim to the facts in the case. But blind acceptance of authority is, fortunately, the exception rather than the rule, and the soundness of a proposition may ordinarily be said to vary directly with the soundness of the evidence supporting it. "The man of science," says Huxley, "has learned to believe in justification, not by faith, but by verification," and one of the most fundamental and striking differences between an uneducated and an educated man is that the first will build innumerable propositions on little or no evidence, whereas the second will build a few propositions slowly and solidly on an abundance of evidence. It would seem, then, that a proposition should be supported upon sound evidence and subjected to as wide a verification as possible.

A complete consideration of the subject of evidence and the induction of hypotheses and propositions from evidence would demand a course in logic. It will be possible here to take up only some of the most general ideas. The supporting elements of a proposition may be based upon actual evidence, gathered by the writer or by others, or upon presumptive evidence. The first is the result of actual observation and verification; the second is based upon logical reasoning which results in the presumption of truths. It is obvious that the soundness of the first type will depend upon the accuracy of the observations, the typical quality of the phenomena observed, and the extent of the verification. The soundness of the second will depend upon the solidity of the basis upon which the built-up tissue of presumptions rests and upon the logic of the reasoning. Propositions may be based entirely upon the personal observations and reasonings of the author or upon these evidences plus those gathered by other persons; often use is made of sub-propositions which have been long established and which are universally accepted. The citation of an authority merely means that the writer, unable personally to subject his proposition to as many verifications as he would like, is depending upon another for further evidence in support of it. But the citation of authorities is often so important a matter in expositions of ideas that it deserves consideration in a separate paragraph.

The citation of an authority in support of a given belief or opinion means, as has been said, the tapping of a vein of evidence wider and more solid than that which the writer has personal access to. An authority is an authority by virtue of the fact that because of his training, his advantageous position, his breadth of experience, and his intellectual powers, his opinions are likely to be solidly based and rationally presented. When we make use of his utterances, we are standing, so to speak, on his shoulders, and are adding his great knowledge to our little. Now, unfortunately, we are likely in our use of authorities to be blind and non-discriminating, to put equal faith in all claimants to authority. For us to do this is natural, for we can assume easily the attitude of mere recipients of second-hand information, and we are, moreover, tempted to save ourselves investigating and thinking. There is no academic phenomenon more generally recognized than the blind faith of the students in authority and especially in printed authority, and no phrase is more familiar to the ear of the thesis-instructor than the wearying, "Where can I get a book on the subject?" These things are written not to deprecate real authority, but simply to warn against non-discriminating faith. For there are sham authorities as well as real authorities empty-headed and untrained and shallow thinkers, who in this easy day of much printing find little trouble in getting their books between covers. A discriminating seeker for support of his beliefs will, therefore, make sure that the authority whom he cites is *favorably,* and not merely *popularly* known, and that the author's training, experience, and demonstrated intellectual powers entitle him to his high claims.

A supplementary word on the subject of authorities should, perhaps, be added. The honest and painstaking writer will be careful in using the opinions or words of another to indicate the source of his borrowings. No attempt need be made to ascribe to any one writer ideas which are universally current, but for a writer to fail in other cases to give credit to his authority is for him to be guilty of literary theft. Failure to give the exact reference, moreover, cuts the reader off from continuing his study in that particular direction. It is always well, therefore, to give as exact a reference as possible.

The value of an exposition of belief or opinion will depend, of course, not only upon the value of the evidence, primary or second-hand, but also upon the soundness of judgment exercised in making use of the evidence. It is perfectly possible, as everybody knows, for a careless and illogical writer so to misuse good evidence as to draw from it conclusions which are quite distorted. No "rules" can be given which will prevent an irrational and untrained mind from such misoperations; the ability to reason solidly from evidence comes from inherent power and from long training. It will be possible, therefore, to point out here only two or three logical fallacies which seem common. The first of these is the tendency, already hinted at, to base wide conclusions on too little evidence. This is the characteristic of the immature and loose thinker; it will be observed that, in general, the more powerful a man's intellect, the more slow will he be to reach a conclusion, and the more firmly established the conclusion, once pronounced, will be. Another frequent fallacy in reasoning comes from the hasty assumption that because two phenomena are concurrent, they are therefore related. Perhaps the most common error, however, is the familiar *post hoc* fallacy, the assumption that because one phenomenon occurs *after* another one, it therefore occurs *as a result of* it. All these errors and many more in handling the evidence in support of a proposition the writer must guard against if he would convince his readers that his proposition is not only based upon sound evidence but is rationally built up from that evidence.

The peculiar difficulties presented by the exposition of ideas lie not only in the fundamental complexities already pointed out, but also in those of actual organization. The problems of selecting and arranging the divisions of a technical description and of a process-exposition are seldom very difficult inasmuch as both selection and order of parts are determined very largely by the subject-matter of the composition. In a technical description the order of parts is suggested by the relationship of certain physical details; in a process-exposition it is essentially chronological. In an exposition of ideas, however, since the material dealt with is fundamentally subjective in nature and not objective, the problems of selection and arrangement of details are much more difficult. For the selection of parts no principles can be laid down inasmuch as the writer must determine in each case after an analysis of his problem just what had best be included and what omitted. For the arrangement of parts—so great is the variation possible—only the most general suggestions can be made, and these should be understood to be not *rules* but general principles only.

A technical description should be planned by groups of concrete details, a process-exposition by stages, an exposition of ideas by topics. These topics which collectively make up the whole exposition will be sometimes loosely, sometimes intimately related. For example, a paper on *The Advantages of Steel in Railway Car Construction* will consist for the most part of an enumeration of advantages, each one being made up of a proposition and its proof. Here the connection between the topics arises merely from the fact that their functions are coördinate; and their relative position is not, therefore, likely to be a matter of very great consequence. In an exposition, on the other hand, in which the entire energies of the writer are bent toward the establishment of a single culminating proposition, that proposition may come as the climax of a long series of interlocked minor propositions, each resting upon its own bed of evidence and reasoning, and each bearing to the preceding propositions a consequential or other close relationship. In an exposition of this carefully built-up type the transposition of a single section may send the whole logical structure crashing to the ground very much as a card-house will tumble upon the disturbance of a single supporting card. In an exposition, then, in which the topics are merely enumerative, the arrangement may be determined by a consideration no more significant than the relative importance of the details enumerated, the most important either being given precedence over the others or reserved for the climax. In an exposition of the second type described the arrangement will be determined, on the other hand, by the logical development of the ideas, and is of the utmost importance for an understanding of the whole. Between these two extremes come expositions presenting various problems of arrangement, the writer being under the necessity in each case of determining what plan seems most logical, most clear, and most emphatic.

Whatever the specific problem of arrangement may be, the writer should invariably observe one principle, he should plan his composition as a whole and not piece by piece. This is especially necessary in expositions in which the relationship of details is consequential rather than merely sequential; for only by planning as a whole can the writer secure real coördination of details and interlocking of parts. In writing each part he should have in mind not only the part being written and the parts which have been written but the parts to come as well, so that he may by anticipation prepare the reader for an understanding of sections lying beyond the part being read. This method will result in a real binding together of the different parts and will prevent disintegration of the whole composition. It is obvious that the writer can secure such coördination only by carefully digesting and planning his material before he begins to write.

Coherence in exposition of ideas can be secured then, especially in expositions which are not merely enumerative in plan, only when the relationship of parts is genuine and logical. An external transition device will no more weld together two parts which have no fundamental relationship than a yoke will make a well-matched team of a horse and an ox. But if a logical relationship really exists between parts, transition devices of various sorts will assist materially in indicating the relationship to the reader. As the value of these "hooks and eyes of style" has already been considered in Chapter III (see pages 43–44), they need only be mentioned here.

Another useful auxiliary device in assisting the reader to follow the plan of the exposition of ideas is the inclusion in the introduction of a brief enumeration of the divisions of the composition. This serves the same purpose in expositions of this type which the general views of the whole object and of the whole process do in technical descriptions and in process-expositions respectively; it serves to provide the reader with a chart of the journey, so to speak, with a view of the whole exposition so that he is better able to relate each part, as he reads it, with all other parts. Such an introductory outline should not be regarded as invariably essential, but in nine cases out of ten its use will provide the reader with a very valuable guide.

Three special subjects not immediately connected with the problems of organization but nevertheless deserving consideration are the introduction, the definition of terms, and the establishment of the point of view of the writer.

A satisfactory introduction to an exposition of ideas which will at once challenge the attention of the reader and escape the charge of being a mere beginning and nothing more is not always easy to write. Introductions will, of course, vary considerably, but they should always be written only after an analysis has been made of the relationship of writer and reader and of the particular demands which the introductions must meet. How this may be done will be shown in a few typical cases. Let it be supposed that the exposition is to be a definition or elucidation. One of the best ways in which to begin is with a question that names the thing to be defined or states the problem to be solved. The rhetorical question runs some risk of being trite, but it is nevertheless often excellent because it causes the reader's mind to reach out for the answer and so allows the writer to slip easily into his explanation. Or take the case of an exposition in which the writer demonstrates and defends a proposition which is either new or at least different from the popular belief. The best introduction for such an exposition is probably that which begins with a statement of the popular belief, for by beginning thus the writer is enabled to build his new theory upon the old, and sometimes too to avoid immediately antagonizing his readers by beginning with a proposition which they may be unwilling to believe. Excepting in those comparatively rare expositions developed inductively, that is, by an array of evidence leading up to a proposition which because of its difficulty is withheld to the end, introductions should usually contain a definite announcement of the subject, and, as has been said above in another connection, a brief enumeration of the parts of the exposition. Often the writer secures a good initial contact with his reader's mind by indicating in the introduction the purpose of the paper or the motive which has prompted him to write it, or by showing the relation between his own exposition and a larger subject to the literature of which he is making a contribution. These elements in introductions are given, of course, only as suggestions; they should not free the writer from the necessity of making a close examination of the individual problems presented with each new exposition.

Failure on the part of the reader to understand an exposition fully may be partly the result of the writer's neglecting to explain the terms which he uses. This neglect involves not only the failure to define technical terms unfamiliar to the reader but, more often, to explain the writer's interpretation of common terms which the reader may have a totally different understanding of. Without such an exposition of the uses made of these terms the writer may write with one set of ideas in his head and the reader read with another set in *his* head, and the two may never get together. Usually such an explanation is made in the introduction, but if the terms involved are not used until well along in the paper, definitions of them had better be reserved until needed.

In expositions of a controversial type and in those which are heavily charged with persuasion it is often important that the writer define his own position lest the reader come to regard him as a prejudiced and self-interested advocate of the ideas expounded, and discount their force accordingly. The writer should show, if he can, that he is entirely dispassionate and disinterested and therefore unbiased in his judgment. Usually this demonstration will fit best into the introduction, but sometimes it will add strength to the argument if it is put last. In many expositions of ideas it is, moreover, sometimes well for the writer to show modestly but directly that he is in a position to speak with some authority. If he indicates briefly the opportunities which he has had to gather evidence in support of statements which he is making, he will run no risk of being accused of conceit, but will simply add to the strength of his contentions.

STUDENT THEMES

[These themes are for class analysis. They are *not designed to serve as models*.]

1. Causes of Cracking of Cement Grouted Brick Pavements

One of the chief difficulties with cement grouted, vitrified brick pavements is that such pavements are subject to extensive cracking. This cracking appears in three forms, bulges or upheavals of the bricks, longitudinal cracks, and transverse cracks.

As might be expected, the bulges or upheavals of the pavement occur only in stretches of the pavement where there are no transverse expansion joints. Breaks of this nature occur very suddenly and with no warning whatsoever, showing that the stresses in the pavement are very high. The reason for such miniature eruptions, as they may properly be called, is very simple. When the pavement is heated up, it increases in size and ought to have room to expand longitudinally, as well as transversely. If no room has been provided by means of transverse expansion joints, the pavement is confined to its original position and enormous compressive stresses are developed. The result is that when the stresses become larger than some portion of the pavement can stand, a section of the pavement buckles up, and room for expansion is provided in that way.

The cause of the formation of longitudinal cracks is not so definitely known. These cracks generally occur at or near the top of the crown and vary greatly in length. One explanation offered is that they are due to unequal heating of the surface of the pavement. This explanation is based on the assumption that the sun shines on the centre of the pavement for a longer period of the day than it does on either side, and consequently the variation of temperature is greater in the centre than on the sides. A much more likely reason, however, is the one which lays the trouble to the action of frost. This explanation is supported by the facts that these cracks always appear first in the spring and that the foundation is also always cracked. Another reason for the formation of this type of crack and the transverse cracks also might be a subgrade which settled in spots leaving the pavement suspended in the air for a short time previous to the cracking.

Aside from the reason just mentioned there is another reason for the formation of transverse cracks. In this explanation it is maintained that a shearing force perpendicular to the curb produces the crack. This shearing force is set up by alternate expansion and contraction of the pavement. To illustrate, we will assume a pavement with plenty of transverse expansion joints but with no soft material as longitudinal joints between the curb and the brick. When expansion occurs, it produces forces in two directions, parallel and perpendicular to the curb. The force parallel to the curb tends to make the bricks move along the street, and the force perpendicular to the curb tends to keep the bricks from moving by increasing the natural friction between the bricks and the curb. As a result a condition obtains which resembles a cantilever beam with a load on the unsupported end. In mechanics it is proved that such a condition will produce a shearing force parallel to the axis of the beam or perpendicular to the curb. When this force becomes excessive, the pavement will crack transversely and relieve the pressure.

2. Dry Sand and Cement Mixture vs. Mortar Bed for Wood Block Pavements

In many of our cities it has been the custom for many years to lay wood block pavements on a concrete base, with a cushion of sand or a bed of mortar between the blocks and the base. To-day it is the custom to put a mixture of dry sand and concrete between the base and the blocks. This latter has proved much more successful than the former one.

A sand cushion is intended primarily to smooth out the roughness of the concrete so that the blocks will rest evenly. Secondly, the yielding surface of the sand permits the roller to press the blocks into it and thus to make an even surface even if the blocks themselves vary a little in thickness. Thirdly, the sand has a slight resiliency and protects the blocks from surface wear. Mortar beds have a similarity in that they act as an evener for the blocks. When mortar gradually hardens, it loses its resiliency and takes on immobility.

There are two main objections to the sand cushion. First, when the blocks are taken up to make any repairs, it frequently happens that months sometimes elapse before the repairs are completed and the blocks relaid; during this time rain works its way between the base and the blocks, thus disturbing a large area, which necessitates the relaying of all the damaged portion. This could not occur with either a mortar bed or cement bed. Second, the resiliency of the sand cushion means unstable support under each block especially the ends and sides, which is of utmost importance to the lasting qualities of the pavement.

The only objection to mortar has been that it must be mixed damp, and time must be allowed for the mortar to set thoroughly before traffic is allowed on the road, whereas a sand cushion permits it to be opened at once. This one objection is now overcome by mixing the mortar dry and allowing the moisture from the ground and air to set it. The roller and immediate travel work the blocks down to the proper height before the mortar sets. Work of this nature has been examined at cuts, and the bed has been found perfect, and the traffic has been allowed on it immediately after it was completed.

Another objection to the old way of mixing mortar damp was that in case the roller broke and could not be repaired at once, all the blocks which had been laid had to be torn up again. The dry method overcomes that objection also. Experience has proved that a mortar bed is far superior to a sand bed.

3. Sand and Mortar Cushions for Wood Block Pavements

Wood block pavements such as are laid at the present time are generally made of the three following layers: the concrete base, the cushion layer of sand or mortar, and the top layer of creosote wood blocks. The cushion layer between the concrete base and the wood blocks serves several purposes, the greatest one of which is implied by its name. By the use of this layer it is also possible to obtain a more smoothly finished surface than if the blocks were laid directly on the rough concrete base.

Two different types of cushion layers are now in use, the one known as the sand cushion, and the other as the mortar bed or mortar cushion. Of these the sand cushion was used earlier, and up to about a year ago was used almost exclusively. It is a layer of clean, sharp sand that has been dampened slightly and rolled before the blocks are laid on it. It is generally from one and one-half to two inches thick, and for a short time after it has been laid, it is a hard cushion to beat. However, after the cushion has been in place for some time, the sand begins to work itself up in the joints between the blocks, and the pavement becomes irregular. Often this upward pressure of the sand in the joints causes a large part of the bituminous filler to be forced out of the joint entirely, and when such a condition occurs, the blocks loosen from one another and must be taken up and relaid.

The mortar cushion has been used now for about a year and so far has been giving better results than the sand cushion. It does not furnish quite so good a cushion as the sand, but it has several advantages that outweigh this one disadvantage. It is made of about one part of cement and four parts of good clean sand, all of which is thoroughly mixed and then spread over the concrete base to a thickness of about one-half inch. It is lightly sprinkled with water just before the blocks are placed, which, with the other ingredients, makes a rich mortar of the layer. This mortar after hardening will not rise up between the blocks, but will aid in holding the blocks in place.

A one and one-half inch sand cushion layer including the rolling costs from six to nine cents per square yard, the amount depending largely upon the kind of sand used and the cost of labor. The mortar cushion layer in place and ready for the blocks costs from five to eight cents per square yard, the cost depending also on the kind of material and the labor. From these figures we see that the mortar cushion layer is the cheaper, and since it has proved so successful during this last year, it will, no doubt, soon replace the sand cushion in all future construction of wood block pavements.

4. The Table of Single Potentials

In the science of electrochemistry, and more particularly in that branch of the science which is known as electrolysis, there is no other unit of information which is so valuable as the table of the single potentials of metals. It is perhaps a little difficult at first to understand just what is meant by the single potential of a metal. If any two different metals be dipped into an electrolyte of any kind, and the leads of a voltmeter be attached to the two different metals, then the voltmeter will register some value of voltage, the magnitude of which depends upon the nature of the two metals and of the electrolyte into which they dip. In this case there is said to be a potential difference between the two metals when placed in the electrolyte. To take a more concrete illustration, if a plate of copper and a plate of zinc be placed in an electrolyte of dilute sulphuric acid, a voltmeter connected between the two plates will register approximately 1.03 volts. Furthermore, it will be found that in the external circuit, *i.e.*, through the voltmeter, the current of electricity is flowing from the copper to the zinc. This means that within the electrolytic cell itself, *i.e.*, through the electrolyte, the current is flowing from the zinc to the copper. Because of this latter fact, zinc is said to be at a higher potential than copper.

In this way we could go on and determine experimentally the potential differences between each metal and every other metal in various electrolytes and could compile more or less useful tables of these values of potential differences. One can easily see, however, that a table giving the potential differences between each metal and each of the other metals would be quite long; in fact, if we were to take only the twenty most common metals, there would be for a single electrolyte two hundred values of potential differences to be experimentally determined and compiled, and for each new electrolyte there would be two hundred more values to be laboriously worked out. To minimize the amount of experimental work, and the size of the tables of potentials, a zero point of potential has been chosen, and to each metal has been assigned a numerical value, known as its "single potential," which in reality represents merely the potential difference between this metal and a hypothetical metal possessing a single potential of zero. From this it will be seen that the zero of single potentials is only a reference point, arbitrarily chosen for the sake of convenience alone, and that it actually has no absolute value in nature. The scale of single potentials may be compared with the ordinary Fahrenheit thermometer scale. In this latter scale the zero point has no absolute significance, and the expressions "ten above zero," or "twenty below zero" merely define certain positions in the whole scale of temperatures. In the same way the single potential value which has been assigned to a certain metal merely defines its position in the whole scale of potentials.

In the scale of single potentials of metals in chloride solution as given below one can easily see the resemblance to the scale of temperatures.

Magnesium	1.231	Tin	−0.085
Aluminium	1.015	Lead	−0.095
Manganese	0.824	Hydrogen	−0.249
Zinc	0.503	Bismuth	−0.315
Cadmium	0.174	Antimony	−0.376
Iron	0.087	Arsenic	−0.550
(Hypothetical)	0.000	Palladium	−1.066
Cobalt	−0.015	Platinum	−1.140
Nickel	−0.020	Gold	−1.356

This table has a number of uses, which may be enumerated as follows:

1. It shows the relative stability of compounds in aqueous solutions; the higher the single potential of the base metal in a compound, the more stable the compound.

2. It gives the voltage that may be expected from a primary cell; for example, if a cell contains the elements zinc and lead, the voltage of the cell will be equal to the algebraic difference between the single potential of zinc and lead. In this case the voltage would be $0.503-(-0.095)$, which is equal to 0.598 volts.

3. It gives the direction of flow of the current in such cells; within the cell itself, the direction of flow will always be from the metal of higher to that of lower potential; externally, of course, the flow will be in the opposite direction.

4. A metal of higher single potential is able to precipitate from a solution of its salt any metal of lower potential.

5. If two metals are in contact and both are exposed to corrosion, then the metal of higher potential will corrode first and will protect the other metal. As an example of this may be cited the coating of iron with zinc to protect it from rusting.

6. If two or more metals are in solution, and this solution is electrolyzed, then the metals of lower single potential will be plated out first by the current.

There are a number of other uses for this table, but to understand such uses one will require a much broader knowledge of the science of electrochemistry than can be covered in this brief paper.

5. The Solution of Problems[1]

In order to obtain the solution of any specific problem various methods may be applied, but experience has shown that there are

[1] Compare *Suggestions on the Study of Mathematics*, p. 216.

usually only a few good methods which will work out satisfactorily, and innumerable bad ones which will not. No matter whether arithmetical, algebraical, geometrical, graphical, calculus, or hybrid methods of solution be used, there are nevertheless certain factors which produce faulty and inaccurate results and others that result in accuracy and logical processes of thought. I shall explain in this paper merely what the difficulties are.

Among the difficulties encountered in the solution of problems and the causes of poor results are: the initial difficulty of choosing the correct method of attack, confusion in handling unknown quantities, lack of neatness and lack of care in each step of the process, and losing the train of thought.

It is often a difficult matter to decide upon the method of solution of a specific problem. One reason to account for this is that the person who is attempting to solve the problem very often imagines that it is necessary for him to see the method of solution in its entirety before he can proceed with the numerical computations, and as a result he usually never gets started. The other extreme is that of a person who blindly tackles a problem without preliminary thought or consideration. His fault is that of misguided energy whereas the other man's is that of lack of initiative. Even though both of these methods enable one to solve very many problems, yet the man who uses them does not derive the mental development that he would receive by adopting more logical methods. Perhaps the most common short-coming of all is that of solving problems by means of fixed types, formulas, or examples, without an understanding of the significance of the terms involved. This is a machine-like method of grinding out solutions and should by all means be avoided.

Unknown quantities in a solution tend to cause confusion because it is then necessary to hunt up sufficient equations to enable one to obtain the desired unknown. At first sight it appears that insufficient data have been given, and for that reason one is often bewildered. The difficulty in handling unknowns is due to the fact that they must be represented by certain expressions which depend upon the conditions in the problem, and must be treated throughout the solution as though they were constants.

Lack of neatness causes many a problem failure either by introducing small errors or by veiling the method of procedure. If a man does not take pains to be neat while working a problem, he then has a marked tendency toward making slight mistakes such as misplacing the decimal point, making illegible figures, or running all the steps in the process into one confused mess. In case a problem is long and complicated, it is seen that he might desire to refer back to the first portion of the solution from time to time in order to follow a logical method of procedure. Consequently, if his work has been put down in poor shape, he will find it difficult to refresh his memory by such a review and may even lose the train of thought which was followed in the first portion of his solution.

If a definite train of thought from start to finish of a problem is not carried out, innumerable working hypotheses crowd upon the mind and produce confusion. For this reason it is better to follow out an incorrect method to the finish, unless one is assured as to its incorrectness before the final stage is reached, than it is to start out with the correct hypothesis and then drift into others which, although correct in themselves, do not combine with the initial one.

6. The Chemical Engineer

As the field of chemical engineering is comparatively new and consequently unknown, the prospective chemical engineer is very often called upon to define exactly the line of work for which his course is preparing him. And just as often he will have to hesitate before making his reply. Although this would seem to indicate that the field of chemical engineering is an indefinite thing, and that its followers are blind wanderers along an unknown path, this is not the case. It is only because he perceives the tremendous scope of his chosen work, and because he realizes his inability to define its limits closely, that the chemical engineering student has to stop and ponder before giving his answer. He knows that, upon leaving college, he will be able to fill competently any one of a number of different positions, but to explain that possibility to the layman in a few comprehensive sentences is to him a difficult matter.

It has been said that the chemical engineer is an industrial chemist. To a certain extent that is true, but as a definition the statement is too limiting. Not only is the chemical engineer the link between the theoretical chemist's laboratory and the practical business man's workshop, but he is also an efficiency engineer, always on the watch for a way in which to simplify a process, cut down a cost, or make use of a hitherto useless by-product. He has been trained not only to know that *A* added to *B* will produce *C*, but also to realize that such an operation will cost a certain number of dollars and cents, which the market value of *C* must recover. And, while the chemist is viewing everything from the laboratory standpoint, the chemical engineer thinks on a commercial scale, realizing that, in the transition from the laboratory to the factory, difficulties will arise to threaten the success of a process which in the laboratory may have seemed to have been well planned.

It is therefore necessary not only that the chemical engineer should be well grounded in all branches of chemistry, but that he should also have a working knowledge of the fundamentals of mechanical, civil, and electrical engineering. And to round him out for contact with business life he must be conversant with the principles of economics and commercial law. He may be said to be a sort of engineering jack-of-all-trades, but, while master of none, he is beginning to combine them all into one, the knowledge of which is making him indispensable in practically every creative industry. In brief, the chemical engineer is a by-product of our modern industrial development and the direct result of an attempt to produce a highly trained technical man who has not been narrowed by specialization, but who has been broadened in spite of it.

7. The Business Man and the College Man

The business man who has never had a college training is apt to look upon the college man as a "smarty" who knows next to nothing. Indeed, this is very often the case with this kind of business man. This attitude is very hard to explain because in most cases it has no solid foundation. If you should ask such a man why he harbors this feeling, he would probably say that the college man thinks that no one but he knows anything. Of course, this may be true of a few college men, but the vast majority, I am sure, are broad-minded enough not to think this or even to show any tendencies in this way. I think that this business man is usually the one who has worked himself up to his position or in other words claims to be a self-made man. He does not see that it is the college man who is becoming more and more the leader in all things and the one who sets the pace of civilization. This hard feeling is indeed deplorable and may be said to be slowly dying out because the self-made man, the man without an education, is becoming scarcer than in former years. If this type of man could be brought into close touch with the college man, it would no doubt benefit both. It would broaden the viewpoint of the business man and give the college man the views of the self-made man.

There is still another type of business man, the one who has had an education or who at least recognizes its value. Between this man and the college man are found the closest sympathies. These two understand each other, and they both realize each other's importance. This kind of business man is the one who makes the college a success and spurs on the average man to acquire an education. He is the one that sets the aim of the college man and gives him inspiration for his work. He is the one who sees the necessity for college training and sees the benefits derived from it. Still there is a lot to be done to improve the relations between the business man and the college man. For example, the college man does not very often appreciate the fact that he, like every one else, must begin at the bottom and work up to the top. He thinks that he is entitled to a big position just because he has an education. The college man is apt to hold his not getting a big position against the business man. But then again this is also fast being stamped out of his mind through the efforts of instructors and business men, and he is beginning to realize the justice of the business man's ways.

8. The Value of Technical Journalistic Work to the Engineering Student

Every student in the university is at some time confronted with the question of the advisability of entering some extra-curricular activity. Student tradition demands that a man do something to distinguish himself outside the class-room. As a result, to some extent, of this tradition, almost unlimited opportunities for such activities afford themselves in the student commonwealth. The engineer, if he be honest, cannot plead guilty of lack of time for such things, for, stiff as his course may be, he invariably has some time in which he has no definite work to do. The question arises, then, as to which direction the engineer's activities should lead him, and it would seem that one of the best answers is found in technical journalism.

Journalism is one of the greatest of all schools of experience. This holds equally true for both the editorial and business departments of the work. It need not be proved by any lengthy discussion that the experience to be gained on a technical magazine is especially valuable to men equipping themselves with a technical education. But some of the more immediate benefits that are outstanding may be mentioned in passing. For the technical student leaning toward the commercial phases of his work there is no better experience to be gained from college life than to solicit advertising from firms who consider such advertising outright charity, a task worthy of comparison with that of the advertising manager of any non-student publication. The handling of such a small enterprise on very close margins and with perhaps little responsibility is a real test of a man's economy, foresight, ingenuity, and strict integrity, which is something more than mere rhetorical integrity.

For the technical student interested in writing the real experience of obtaining the right material at the right time from the right man,—a problem in keenness of observation,—of editing that material in the right way in order to give it its best appearance without destroying too much of the author's original form, of getting that material printed in the right way in order to draw its proper share of attention,—such experience is to be found just as well in the student as in the non-student publication. The smaller details of the work round out that experience to a full fruitage.

It is of especial value to a man to carry a certain share of fixed responsibility and to carry it without tangible recompense. In the little share of glory that a man gets from a year's work on the staff of a student publication there is little of the wherewithal on which to live from board bill to board bill. It is comparatively easy to do an assigned amount of work when there is a pay envelope to follow at the end of the week, but when the stimulus has to be the joy of working, the work does not progress so smoothly.

There is one thing to be gained from work on such a magazine which is often misinterpreted by some persons. It follows naturally in a school where the faculty are interested in the school publication that the students working on the publication are brought more or less under the attention of the faculty men. The chronic cynics brand this type of activity, therefore, as "working for a stand-in." No faculty man can be blamed for failing to recognize a man's merits if he willfully hides himself in the crowd. Nor can any student be blamed for trying to raise his head just a trifle above those around him so that the instructor may at least recognize him as an individual in the crowd. This does not foreshadow a phenomenal rise in the standings of that student. The results seldom show during a man's college course. But the time will come, perhaps at graduation, perhaps some years later, when the mere fact that the man's head was raised just a trifle higher than those about him will throw the balance of influence in his favor. And thus the work is, even in this respect, an excellent preparation or the long years after commencement.

EXPOSITIONS OF IDEAS

ELECTRIC HEATING DEVICES[1]

JOHN F. ROBERTSON

[A frequent type of technical exposition is the letter to the editor of a technical magazine from a writer who wishes to comment briefly and informally upon some matter which he believes worth the notice of the readers. Such a letter, on a commercial aspect of the profession, follows. It is suggested that a profitable theme would be the writing of a letter to the editor of the college or other engineering magazine.]

To the Editors of Electrical World:

SIRS:—It is strangely singular, though by no means inexplicable, how central-station managers, and solicitors in particular, will induce a consumer to load up his circuits with almost every conceivable form of electric-heating device without any thought as to the ability of the consumer to keep such apparatus in operation. Seldom—and this point has been emphasized often—does the manager or solicitor stop to ask himself whether the consumer's income is such as to warrant the installation of certain heating devices, especially if the energy is not sold at very low rates. It is generally admitted that unless low rates for heating circuits prevail, it is out of the question for an average clerk to roast meats in an electric oven in competition with other fuel, unless, of course, there are very urgent reasons for using electricity.

The average solicitor, if he felt that a consumer would take his advice, would suggest that the entire house be electrically equipped, and could frame up enough arguments to convince an easily-led individual that that would be the proper thing to do. This is not only detrimental to the central station and to the manufacturer of heating devices, but to the whole art as well. Even customers

[1] Reprinted from the *Electrical World* by permission of the publishers.

who can afford to pay high rates in return for the cleanliness and convenience of electricity, have installed cooking and heating apparatus often at great expense, and discarded it again after a short period of use. Granting that the apparatus itself is thoroughly reliable, it is but right that a consumer be apprised of all the facts in connection with it. The luminous radiator, for instance, is a very pretty piece of apparatus; but as an economical heat producer it is an admitted failure, and for a manager to push apparatus of this kind without stating that it is especially serviceable for bathrooms, sitting-rooms, etc., where heat is required for short periods of time only or to take the chill off the room, only tends to bring discredit and to hinder the legitimate development of the business in other directions. Unless a man has a fairly large income, can he afford to place electric cooking utensils in the hand of the average cook in a family of more than five, for instance? In the first place, the cost of some kettles is such that it would be possible for the same sum to buy a whole outfit of ordinary cooking utensils. Renewals are also costly, and if the manufacturers of heating apparatus would make heating elements in sections and make them as readily replaceable as fuses in a circuit, for example, progress will be made.

There are numerous devices on the market which are very serviceable and which come within the means of even the poorest, or at least anyone having electricity in his dwelling. The first cost is usually the only hindrance to their introduction, and if central stations would rent these as they do flat-irons, etc., on a basis commensurable with their convenience, the general public will be likely to entertain the suggestion of the most persuasive and eloquent canvassers employed. There is no doubt a field for extensive operations in this direction if approached in the proper manner. That manner is certainly not to try to bankrupt a consumer by installing apparatus consuming more energy than he is able to buy.

A manager may as well be frank with a patron of his company, and if in his estimation it would be detrimental to the interests of a customer to install certain apparatus, although seemingly advantageous to the electric-light company at first, it would be wise for him so to advise the customer. Such frankness and solicitude always bring their reward.

NEW YORK. JOHN F. ROBERTSON.

How to Use the Technical Journal[1]

Paper (Slightly Condensed) by John W. Alvord, Consulting Engineer, of Chicago, Presented at the Convention of the Federation of Trade Press Associations, Chicago, September 24–26.

[The following article is reprinted partly because it affords a good illustration of expository analysis and classification and partly because of its relation to the general subject of writing and reading engineering articles. It is suggested that it be used as the basis for a class discussion of the value and use of the engineering journal and for a theme on *How I Read My Engineering Journal*, *The Make-up of My Engineering Journal*, *Why I Like the ——(name of technical journal)——*, *Some Suggestions for Indexing and Clipping Engineering Journals*, or some similar subject designed to stimulate interest in the important matters of reading intelligently and preserving information economically. The brief editorial comment on Mr. Alvord's paper was taken from the *Engineering Record* of the same date and is here reproduced with the thought that it might add interest to the reading of the main article.]

In 1880, when the writer first commenced to take some interest in technical journals, such publications in this country were relatively few. We had the Engineering News (1874), the Sanitary Engineer and Building Record (1880) (now the Engineering Record) Van Nostrand's Magazine (now defunct), the American Engineer and Railway Journal (1832), the Railway and Engineering Review (1864), Railway Age Gazette (1856), the Engineering and Mining Journal (1866), the Electrical World (1874), and a number of trade papers of some interest to engineers. Only the railway

[1] Reprinted from the *Engineering Record* for October 3, 1914, by permission of the publishers. The condensing was done by the publishers from the original paper.

journals were really financially able to cover the ground in their respective fields. All were far less comprehensive than at present. In 1880, the engineer treasured and indexed almost every scrap of printed matter on any engineering subject that came his way. To-day his task is to sort out, discard, and eliminate that which he can no longer use, and limit himself to the inspection and reading of that which bears principally on his selected professional specialty.

That we cannot keep abreast of the times without reading the engineering journals is obvious. That if we carefully read all the engineering journals in our chosen specialty we would have no time left to earn a living is easily capable of demonstration. What then is the proper attitude to adopt toward this ever-increasing flood of information that pours in upon us so relentlessly?

Subscribers' Attitude toward Paper

If we look about us to see how our fellow engineers solve this matter we shall find a great variety of attitudes toward the problem. Some engineers simply do not take engineering journals, reading one occasionally here and there as opportunity offers. Others take all they can afford to take and let them pile up around the office, often unopened and unused. Others still limit themselves to a select few, which they carefully bind and shelve. Still others read journals when they can, and throw them away when they move on. As a rule, however, the engineer prizes his technical paper, and endeavors in some ill-defined and formless sort of fashion to preserve its information for future use. Generally he fails to find any practicable scheme which makes his rapidly accumulating material of much value to him after it has once passed under his eye, and for a large number of engineers, technical journals are only professional newspapers with which to idle away an hour or so and satisfy their curiosity. That their value is something much more than this, or should be more than this, is so apparent as to need no denial.

The problem of the engineer with his technical paper is much affected by his age, station and aim in life. To the man who is in engineering only to get money and more money, the engineering journal is a newspaper, in which he may notice mainly where there are better jobs than his own that may be sought after and perhaps obtained. To the man who is anxious to fit himself every year of his life for something better it is an opportunity, quite unequaled many years ago, for a great variety of study. To the young engineer the engineering journal, properly read and noted, is a part of a post-graduate course in engineering. To the middle-aged man it is a mine of data, bearing in all sorts of ways on his work; and to the mature specialist only does it begin to become burdensome by its repetition of experience, and its volume of matter on subject which has already, to him at least, been well digested. Let us see if we can outline how each of these classes can get more profit out of the matter contained in the engineering journals than do the careless or the indifferent, who, after their journal is once looked over, let it go to waste or idleness.

Problem of Young Engineer

The young engineer and the college graduate need, most of all, practical experience. It is safe to say that engineering literature will never have any proper perspective for him until he has been connected in some capacity with engineering work himself, be it in ever so modest a capacity. With the actual doing of engineering work, however, should come contemporaneously the reading of technical journals, particularly along the lines in which he is working. Nothing can be more instructive, broadening, and enlightening to a man doing a particular kind of work than reading about similar work at the same time. It follows, therefore, that the young engineer should as early as possible, take at least one first-class engineering journal and own it himself; bind it if he can afford to, but lay it away in an orderly manner, in any event. If he can afford two journals so much the better, especially if they are selected so as to widen his outlook.

It is to be doubted if laborious reading of all kinds of engineering articles all the time is advisable for anyone. Mere quantity of reading is mentally detrimental. If one might advise, it would be to suggest enforced systematic reading of all articles particularly bearing on the line of work the reader is immediately engaged upon, and the optional reading only of such other articles as interest him. This ought not to be much of a task. In course of time as his experience broadens, engineering reading will become less burdensome and more interesting because its relation to practical matters will be more and more appreciated, and the discriminating use of engineering literature better understood. Of course, all this applies to engineering societies as well; but that is another story.

Card Index Caution

It is probably not wise for the young engineer to indulge extensively in card indexes, filing systems, and the like, for topically arranging his available engineering journal articles. Few men know very early in life where fate and interest will land their future attention, and filing systems and special indexes are expensive and time consuming, and when indulged in without definite aim nearly always quickly become too voluminous and thereby useless. If any suggestions are made along this line, it would be to start a loose leaf, letter-size ($8\frac{1}{2} \times 11$-in. page) notebook and note in it (separate pages for separate subjects) only what appears to be extremely useful, either in exceedingly brief abstracts from engineering articles, or diagrams, costs, etc.

The young engineer is tempted to read much about large enterprises—the Panama Canal, big bridges, astonishing tunnels, great dams. This does no harm, and probably holds his interest for the time being. Gradually he learns that, for him at least, the chief value of the technical journal does not lie in its dramatic side, necessary as that may be for our general information, interest and pleasure, but its chief value lies in a fund of small things, which make up routine work of the ordinary every-day job. These are to be watched for, and noted, as practically useful to the average man.

The Middle-aged Reader

We next come to the man in early middle life, actively engaged in his profession, and note at once that his problem with the technical journal is the absence of "time." Absorbed in a multitude of responsibilities, harassed with unexpected difficulties, worn out at night with the long day of strain, how shall he derive any useful good from the multitude of journals which his more ample income can readily afford, but which pile high on his table after every brief absence from the office? Whether or not such an engineer shall make any effort to systematically assimilate, file, and study current technical journals depends in part upon the nature of his routine. If he is largely engaged in administrative work, or is a salaried officer in a large enterprise with a comparatively limited range of problem or a limited call for miscellaneous data, he may generally be content with a cursory examination of the engineering journal such as will keep him qualified on his undertaking, and the preservation of such journals in bound form, with the standard published indexes. If, however, he is entering upon novel work, or work presenting a great variety of problems, overlapping into a great variety of fields, ambition will compel him to do more than this, and some form of special indexing will appeal to him more or less strongly as he feels the need more often for research in up-do-date material.

The average editor can judge of a technical article with only a brief inspection—a sentence here and there, a headline, and a moment's reading of the summary and conclusion. Long familiarity with matter of a similar character gives him the assurance that he can detect in this rapid review anything novel, new, or original, and can fairly pass judgment upon it in a general way. The working engineer who has had some experience with technical literature can form the same habit, and save much time. It is really wonderful how much repetition there is in engineering writing and in the production of engineering papers. It thus happens that we are under the necessity of seeing much the same facts and principles repeatedly published in varying form, for some one is always attracted to really read them, with consequent benefit to himself, under the belief that they are new and novel.

The mature engineer notes that a large amount of engineering literature is of the purely descriptive order, merely giving outline of work that has been accomplished, without going into reasons or principles. All this kind of writing is valuable and useful, and has its proper place, but all of this class of literature has its limitations. One of the most severe of its limitations is that it rarely describes mistakes, errors of judgment, or failures, and in these lie the most valuable lessons to the seeker after truth. One is obliged to read between the lines or read with reservation, much as one does in reading accounts of battles in the daily press. It is always wise to look back and note the origin of the despatches in such cases.

A tremendous lot of engineering literature is written which is of little permanent value. Often it represents the writer's struggles to understand a subject. Often it is compiled largely from a desire for publicity. Fortunately the editors of the technical papers can limit this kind of reading by care in selection.

Separating Wheat from Chaff

But amid all these drawbacks a discriminating mind will always find a great deal of wheat amid the chaff, and the wheat that will be gleaned will be of differing kind and amount, depending upon the type of mind of the reader, his present problem, and his desire to systematize his information. What, therefore, shall he do with his special selection when once he thinks he has separated it from the flood of raw material?

Several courses are open to him:

First, he may rely on his memory and the published index to his bound volumes. It is safe to say, however, that few engineers really make much practical use of this method. The intervening index and the bother of a search prove to be discouraging to that degree that a proposed reference search is abandoned in about one-half the suggested attempts. The ideal filing system is one in which, with the least amount of effort, one can put his hand immediately and accurately on the thing itself, be it a book, a pamphlet, or a data sheet.

Second, he may keep a special card index of important data and reference to valuable articles. This at once involves labor and attention which few busy men can give and which, if done by assistants or librarians, largely loses its personal value to the one who needs it. The same objection as to the discouraging effect of intervening indexes holds good here, too, and it is further safe to say that of all the contrivances for indexing the most difficult to handle readily and examine rapidly is the card index system.

Third, he may abstract important data in a limited way on loose leaf transparent paper, standard letter-size, and he may remove or detach articles of special value from out his journals, to be filed in regular office file system, like correspondence.

The writer has tried all of the above methods at considerable cost in time and patience, and has, for many years, settled upon the third method. With all its admitted limitations it seems to be the best for an office which is expected to find out information on a great variety of subjects in a limited time, and with the least amount of effort.

Data for Reference

Some description of its practical workings may be of interest:

All the technical papers of the office pass on to the desk of the head of the office and are at least looked over (not read) by him. Articles important to his particular specialty are checked with pencil, and articles of especial interest are looked over with care and double checked. Once in a long while data important enough to go to the data file are noted. This is either especially abstracted by the stenographer, or, if a diagram or cost data, perhaps traced in the drafting room, all on transparent paper for copying purposes. Special data of this kind, on $8\frac{1}{2} \times 11$-in. sheets, are filed in the office data file (a separate but common standard correspondence file). From the data file loose-leaf working note-books are made up from blueprints for office or travel purposes. They are altered, refilled, amended and sorted back from time to time as needed to keep them of usable volume and usefully up-do-date.

The technical journals, with checked articles, go to the office clerk or the stenographer at odd hours, or the librarian if one can be afforded, and the useful articles are removed by tearing them out with a ruler. They are folded, usually once, to standard size, with one edge lap left for binding, and are then filed in a subject index file, like current correspondence. The Dewey Decimal system, especially arranged for the office, is used, but only as a general subject plan. When the file is full, portions of its contents, especially that which is most useful, are simply bound in plain pasteboard covers and placed in the library shelves, with titles. Such a book (or many books) would contain all the recent articles thought to be of special value on a given single subject. The remaining portions of the technical paper are thrown away, but in a large office, warranting the expense, duplicate bound copies can be kept as well, with the general published index as their key.

Objections and Advantages

The objections to this system are as follows:

First, it is too expensive for any but the most important offices doing specialized work. Second, data accumulate almost too fast unless rigidly kept down to a minimum. Third, it requires some personal attention of the head of the office, a competent assistant, or the employment of a regular librarian.

The advantages are:

First, it compels the office head to know all the time what is being published in current engineering literature, if only by inspection. Second, it removes all intervening indexes between the searcher and the final repository in bound volume. Third, it keeps one's library usefully up-to-date on all lines in which one should be especially interested. Fourth, it is economical of final shelf room and cost.

Obviously, one should not start so elaborate a system as this unless he is fairly sure of the special line of engineering to which his life will be devoted. Otherwise, waste effort and discouragement will be certain. It is not to be recommended to the young man, but only to the mature man of early middle life when his work clearly indicates the necessity for it. It is, however, the prime requisite of the engineering specialist. To him some such a system is invaluable. Not a few consulting engineers use this standardized system interchangeably, particularly the data file, thereby greatly increasing its usefulness to one another as a joint effort.

We come finally to the mature and experienced engineer of advancing years. How can he make engineering and technical literature of use? It is safe to say that when an engineer has much passed fifty or sixty years of age and has led an active life, his need for engineering literature lessens. Out of the mass of detail which seemed to him so overwhelming and endless in his youth and early manhood, fundamental principles emerge like peaks out of the clouds, and upon these as foundation all detail classifies itself simply and naturally, and therefore, he feels less need for accumulated data or particular description. Probably no one enjoys engineering reading as does the mature engineer, for he can read between the lines and find much to instruct as well as interest, and yet while he is probably the most interested and intelligent reader of engineering literature that the journals have, his ambition as a collector is gone and filing systems no longer appeal to him.

If his acquaintance is wide, he reads with interest the accomplishments of his friends, and the addresses of society presidents and articles on the ethics of the profession. Of failures he is the keen student. The personal column appeals to him, and if he is of right-mindedness he is conscious of more pleasure than formerly in the accomplishments of those who have succeeded and succeeded well in dire and burdensome responsibility. More often than the young man he will turn back for his satisfaction to papers that served him well in times past, and perhaps smile at the lack of improvement that later attempts to deal with their subject often show.

Technical papers, along with the technical societies and their proceedings, form the repository of the professions; they are the interchange of experience, the common store upon which we all draw. Without them we would be strangely helpless. We are indebted to every one more or less who records his experience for the common use, and that debt we should endeavor to helpfully repay in kind, but wisely, concisely and thoughtfully.

Reading Technical Journals[1]

In the qualifying tests of marksmanship which are now a regular part of our army routine, it is always instructive to stand behind a pair of men on the firing line at a rifle range and watch the effect of their shots. Rifles, ammunition, targets and range are the same for both, yet one will score an unbroken string of bull's-eyes and "four's" while the other will turn in a card of "three's," "two's" and "misses." The first man knows how to use his weapon; the second, with the same weapon, gets poor results.

These two soldiers are typical of two classes of readers of the technical journal. To each class the publisher sends the same sort of munitions in printed form each week. One will take this material and with it score effectively in his own work, while the other receives, comparatively, little benefit. In this issue John W. Alvord gives an instructive lesson in the use of the technical periodical. His paper was read last week before the Federation of Trade Press Associations in Chicago and is reprinted on page 375. He analyzes the cases of the young engineer, the mature reader, who "has no time to read," and the veteran with years of experience behind him. For each the modern technical journal has something to offer, if the reader will only take the trouble to learn how to find it. Mr.

[1] Editorial comment on Mr. Alvord's paper reprinted from the *Engineering Record* for October 3, 1914, by permission of the publishers.

Alvord's paper is replete with helpful hints on what to read, what not to read and how to preserve engineering data for future reference.

The editor of to-day, in contrast with his predecessor of a decade ago, faces each morning an imposing mound of manuscript—far in excess of the space available for contributions—and from this he selects his articles. The field of civil engineering is so broad that a wide range of subjects must be covered by the paper which conscientiously serves all its readers. Manifestly every story will not interest every subscriber. In these days of specialization, therefore, the reader must learn to estimate the value of each article from the standpoint of his own needs and concentrate upon those which apply to his particular work. Technical journalism has by no means reached a stage which might be called perfection. Even an editor will admit this frankly, but the technical paper has established for itself a place in engineering progress and with the coöperation of its readers an even larger field of usefulness lies before it.

The Method of Scientific Investigation[1]

Thomas Henry Huxley

[No apology need be made for again reprinting this much used lecture by Huxley. Huxley's mastery of exposition consists largely in his ability to adopt the point of view of his audience. The elements of good exposition to be noted here are: (1) his clear inductive explanation of abstract terms, (2) his wealth of simple illustration, (3) his clean-cut division of material, and (4) his easy style, characterized by playfulness of manner, sympathy with his audience, and avoidance of technical or otherwise difficult words.]

The method of scientific investigation is nothing but the expression of the necessary mode of working of the human mind. It is simply the mode at which all phenomena are reasoned about,

[1] The first part of the third lecture of a series of *Six Lectures to Workingmen on the Phenomena of Organic Nature,* 1863.

rendered precise and exact. There is no more difference, but there is just the same kind of difference, between the mental operations of a man of science and those of an ordinary person, as there is between the operations and methods of a baker or of a butcher weighing out his goods in common scales, and the operations of a chemist in performing a difficult and complex analysis by means of his balance and finely-graduated weights. It is not that the action of the scales in the one case, and the balance in the other, differ in the principles of their construction or manner of working; but the beam of one is set on an infinitely finer axis than the other, and of course turns by the addition of a much smaller weight.

You will understand this better, perhaps, if I give you some familiar example. You have all heard it repeated, I dare say, that men of science work by means of Induction and Deduction, and that by the help of these operations, they, in a sort of sense, wring from Nature certain other things, which are called Natural Laws, and Causes, and that out of these, by some cunning skill of their own, they build up Hypotheses and Theories. And it is imagined by many, that the operations of the common mind can be by no means compared with these processes, and that they have to be acquired by a sort of special apprenticeship to the craft. To hear all these large words, you would think that the mind of a man of science must be constituted differently from that of his fellow-men; but if you will not be frightened by terms, you will discover that you are quite wrong, and that all these terrible apparatus are being used by yourselves every day and every hour of your lives.

There is a well-known incident in one of Molière's plays, where the author makes the hero express unbounded delight on being told that he had been talking prose during the whole of his life. In the same way, I trust, that you will take comfort, and be delighted with yourselves, on the discovery that you have been acting on the principles of inductive and deductive philosophy during the same period. Probably there is not one here who has not in the course of the day had occasion to set in motion a complex train of reasoning, of the very same kind, though differing of course in degree, as that which a scientific man goes through in tracing the causes of natural phenomena.

A very trivial circumstance will serve to exemplify this. Suppose you go into a fruiterer's shop, wanting an apple,—you take up one, and, on biting it, you find it is sour; you look at it, and see that it is hard and green. You take up another one, and that too is hard, green, and sour. The shopman offers you a third; but, before biting it, you examine it, and find that it is hard and green, and you immediately say that you will not have it, as it must be sour, like those that you have already tried.

Nothing can be more simple than that, you think; but if you will take the trouble to analyze and trace out into its logical elements what has been done by the mind, you will be greatly surprised. In the first place, you have performed the operation of Induction. You found that, in two experiences, hardness and greenness in apples went together with sourness. It was so in the first case, and it was confirmed by the second. True, it is a very small basis, but still it is enough to make an induction from; you generalize the facts, and you expect to find sourness in apples where you get hardness and greenness. You found upon that a general law, that all hard and green apples are sour; and that, so far as it goes, is a perfect induction. Well, having got your natural law in this way, when you are offered another apple which you find is hard and green, you say, "All hard and green apples are sour; this apple is hard and green, therefore this apple is sour." That train of reasoning is what logicians call a syllogism, and has all its various parts and terms,—its major premiss, its minor premiss, and its conclusion. And, by the help of further reasoning, which, if drawn out, would have to be exhibited in two or three other syllogisms, you arrive at your final determination, "I will not have that apple." So that, you see, you have, in the first place, established a law by Induction, and upon that you have founded a Deduction, and reasoned out the special conclusion of the particular case. Well now, suppose, having got your law, that at some time afterwards, you are discussing the qualities of apples with a friend: you will say to him, "It is a very curious thing,—but I find that all hard and green apples are sour!" Your friend says to you, "But how do you know that?" You at once reply, "Oh, because I have tried them over and over again, and have always found them to be so." Well, if we were talking science instead of common sense, we should call that an Experimental Verification. And, if still opposed, you go further, and say, "I have heard from the people in Somersetshire and Devonshire, where a large number of apples are grown, that they have observed the same thing. It is also found to be the case in Normandy, and in North America. In short, I find it to be the universal experience of mankind wherever attention has been directed to the subject." Whereupon, your friend, unless he is a very unreasonable man, agrees with you, and is convinced that you are quite right in the conclusion you have drawn. He believes, although perhaps he does not know he believes it, that the more extensive Verifications are,—that the more frequently experiments have been made, and results of the same kind arrived at, —that the more varied the conditions under which the same results are attained, the more certain is the ultimate conclusion, and he disputes the question no further. He sees that the experiment has been tried under all sorts of conditions, as to time, place, and people, with the same result; and he says with you, therefore, that the law you have laid down must be a good one, and he must believe it.

In science we do the same thing;—the philosopher exercises precisely the same faculties, though in a much more delicate manner. In scientific inquiry it becomes a matter of duty to expose a supposed law to every possible kind of verification, and to take care, moreover, that this is done intentionally, and not left to a mere accident, as in the case of the apples. And in science, as in common life, our confidence in a law is in exact proportion to the absence of variation in the result of our experimental verifications. For instance, if you let go your grasp of an article you may have in your hand, it will immediately fall to the ground. That is a very common verification of one of the best established laws of nature—that of gravitation. The method by which men of science establish the existence of that law is exactly the same as that by which we have established the trivial proposition about the sourness of hard and green apples. But we believe it in such an extensive, thorough, and unhesitating manner because the universal experience of mankind verifies it, and we can verify it ourselves at any time; and that is the strongest possible foundation on which any natural law can rest.

So much, then, by way of proof that the method of establishing laws in science is exactly the same as that pursued in common life. Let us now turn to another matter (though really it is but another phase of the same question), and that is, the method by which, from the relations of certain phenomena, we prove that some stand in the position of causes towards the others.

I want to put the case clearly before you, and I will therefore show you what I mean by another familiar example. I will suppose that one of you, on coming down in the morning to the parlour of your house, finds that a tea-pot and some spoons which had been left in the room on the previous evening are gone,—the window is open, and you observe the mark of a dirty hand on the window-frame, and perhaps, in addition to that, you notice the impress of a hob-nailed shoe on the gravel outside. All these phenomena have struck your attention instantly, and before two seconds have passed you say, "Oh, somebody has broken open the window, entered the room, and run off with the spoons and the tea-pot!" That speech is out of your mouth in a moment. And you will probably add, "I know there has; I am quite sure of it!" You mean to say exactly what you know; but in reality you are giving expression to what is, in all essential particulars, an Hypothesis. You do not *know* it at all; it is nothing but an hypothesis rapidly framed in your own mind! And, it is an hypothesis founded on a long train of inductions and deductions.

What are those inductions and deductions, and how have you got at this hypothesis? You have observed, in the first place, that the window is open; but by a train of reasoning involving many Inductions and Deductions, you have probably arrived long before at the General Law—and a very good one it is—that windows do not open of themselves; and you therefore conclude that something has opened the window. A second general law that you have arrived at in the same way is, that tea-pots and spoons do not go out of a window spontaneously, and you are satisfied that, as they are not now where you left them, they have been removed. In the third place, you look at the marks on the window-sill, and the shoe-marks outside, and you say that in all previous experience the former kind of mark has never been produced by anything else but the hand of a human being; and the same experience shows that no other animal but man at present wears shoes with hob-nails in them such as would produce the marks in the gravel. I do not know, even if we could discover any of those "missing links" that are talked about, that they would help us to any other conclusion! At any rate the law which states our present experience is strong enough for my present purpose. You next reach the conclusion, that as these kinds of marks have not been left by any other animals than men, or are liable to be formed in any other way than by a man's hand and shoe, the marks in question have been formed by a man in that way. You have, further, a general law, founded on observation and experience, and that, too, is, I am sorry to say, a very universal and unimpeachable one,—that some men are thieves; and you assume at once from all these premisses—and that is what constitutes your hypothesis—that the man who made the marks outside and on the window-sill, opened the window, got into the room, and stole your tea-pot and spoons. You have now arrived at a *Vera Causa;*—you have assumed a Cause which it is plain is competent to produce all the phenomena you have observed. You can explain all these phenomena only by the hypothesis of a thief. But that is a hypothetical conclusion, of the justice of which you have no absolute proof at all; it is only rendered highly probable by a series of inductive and deductive reasonings.

I suppose your first action, assuming that you are a man of ordinary common sense, and that you have established this hypothesis to your own satisfaction, will very likely be to go off for the police, and set them on the track of the burglar, with the view to the recovery of your property. But just as you are starting with this object, some person comes in, and on learning what you are about, says, "My good friend, you are going on a great deal too fast. How do you know that the man who really made the marks took the spoons? It might have been a monkey that took them, and the man may have merely looked in afterwards." You would probably reply, "Well, that is all very well, but you see it is contrary to all experience of the way tea-pots and spoons are abstracted; so that, at any rate, your hypothesis is less probable than mine." While you are talking the thing over in this way, another friend arrives, one of that good kind of people that I was talking of a little while ago. And he might say, "Oh, my dear sir, you are certainly going on a great deal too fast. You are most presumptuous. You admit that all these occurrences took place when you were fast asleep, at a time when you could not possibly have known anything about what was taking place. How do you know that the laws of Nature are not suspended during the night? It may be that there has been some kind of supernatural interference in this case." In point of fact, he declares that your hypothesis is one of which you can not at all demonstrate the truth, and that you are by no means sure that the laws of Nature are the same when you are asleep as when you are awake.

Well, now, you can not at the moment answer that kind of reasoning. You feel that your worthy friend has you somewhat at a disadvantage. You will feel perfectly convinced in your own mind, however, that you are quite right, and you say to him, "My good friend, I can only be guided by the natural probabilities of the case, and if you will be kind enough to stand aside and permit me to pass, I will go and fetch the police." Well, we will suppose that your journey is successful, and that by good luck you meet with a policeman; that eventually the burglar is found with your property on his person, and the marks correspond to his hand and to his boots. Probably any jury would consider those facts a very good experimental verification of your hypothesis, touching the cause of the abnormal phenomena observed in your parlour, and would act accordingly.

Now, in this supposititious case, I have taken phenomena of a very common kind, in order that you might see what are the different steps in an ordinary process of reasoning, if you will only take the trouble to analyze it carefully. All the operations I have described, you will see, are involved in the mind of any man of sense in leading him to a conclusion as to the course he should take in order to make good a robbery and punish the offender. I say that you are led, in that case, to your conclusion by exactly the same train of reasoning as that which a man of science pursues when he is endeavouring to discover the origin and laws of the most occult phenomena. The process is, and always must be, the same; and precisely the same mode of reasoning was employed by Newton and Laplace in their endeavours to discover and define the causes of the movements of the heavenly bodies, as you, with your own common sense, would employ to detect a burglar. The only difference is, that the nature of the inquiry being more abstruse, every step has to be most carefully watched, so that there may not be a single crack or flaw in your hypothesis. A flaw or crack in many of the hypotheses of daily life may be of little or no moment as affecting the general correctness of the conclusions at which we may arrive; but in a scientific inquiry a fallacy, great or small, is always of importance, and is sure to be in the long run constantly productive of mischievous, if not fatal results.

Do not allow yourselves to be misled by the common notion that an hypothesis is untrustworthy simply because it is an hypothesis. It is often urged, in respect to some scientific conclusion, that, after all, it is only an hypothesis. But what more have we to guide us in nine-tenths of the most important affairs of daily life than hypotheses, and often very ill-based ones? So that in science, where the evidence of an hypothesis is subjected to the most rigid examination, we may rightly pursue the same course. You may have hypotheses and hypotheses. A man may say, if he likes, that the moon is made of green cheese: that is an hypothesis. But another man, who has devoted a great deal of time and attention to the subject, and availed himself of the most powerful telescopes and the results of the observations of others, declares that in his opinion it is probably composed of materials very similar to those of which our own earth is made up: and that is also only an hypothesis. But I need not tell you that there is an enormous difference in the value of the two hypotheses. That one which is based on sound scientific knowledge is sure to have a corresponding value; and that which is a mere hasty random guess is likely to have but little value. Every great step in our progress in discovering causes has been made in exactly the same way as that which I have detailed to you. A person observing the occurrence of certain facts and phenomena asks, naturally enough, what process, what kind of operation known to occur in nature applied to the particular case, will unravel and explain the mystery? Hence you have the scientific hypothesis; and its value will be proportionate to the care and completeness with which its basis had been tested and verified. It is in these matters as in the commonest affairs of practical life: the guess of the fool will be folly, while the guess of the wise man will contain wisdom. In all cases, you see that the value of the result depends on the patience and faithfulness with which the investigator applies to his hypothesis every possible kind of verification.

THE WEB-FOOT ENGINEER[1]

BENJAMIN BROOKS

[The following is a "popular science" exposition, an explanation of the work of the "web-foot" engineer stripped of its technicalities and otherwise adapted to the understanding of the general reader. Among the compositional elements which should be noted here are:

[1] Reprinted by permission of the publishers from *McClure's Magazine*, Vol. XXXIII, p. 73.

(1) The clear arrangement and careful indication of divisions; (2) the adaptation to the reader, involving an expository plan by which the simple outlines of the engineering processes explained are given first and the more complicated details later, an avoidance of technical terms, and frequent striking analogies which the general reader can readily understand; and (3) the color and individuality of the style, which is characterized by concreteness and novelty of expression, easy humor, and pleasing suggestion of big men dauntlessly solving big problems.]

While the "tallest building in the world"—which is always being built somewhere in New York—continues to absorb popular wonder and attention, and the great cantilevers and suspension-bridges continue to bear up under their weight of criticism without visible means of support, the most important but least spectacular individual concerned in their existence continues his unobtrusive subterranean operations almost unknown, except as he may from time to time annoy us with the blocking of a thoroughfare or the creation of a local earthquake. Thus the term "skyscraper" is an old one, while the term "earthscraper" was invented but yesterday. I have spoken of this retiring person as web-footed because, as with ducks and cranes and other animals thus endowed by nature, the business of his life is in the mud, the shifty quicksand, and under water; and whatever he may lack in the spectacular or picturesque, he is nevertheless most worthy of notice for his unequalled ingenuity.

The web-foot engineer has three main problems to deal with: to support a tremendous weight over soft mud or quicksand; to open and maintain a clear passage through it; to drain it off and eliminate it altogether. Out of these three main problems grow an endless combination of difficulties that he must devise means of overcoming; but in all of them enters his arch-enemy, water —water, the basis of all big engineering, locater of railways and thoroughfares, distributor of population, maker of treaties, destroyer of man's half-baked, faint-hearted attempts, but conserver of his truly great works.

There is an old, shop-worn fallacy that the great man is always at hand awaiting the occasion that will bring him out of oblivion and put him on his mettle; but the two greatest cities in the world both waited years in an overcrowded, river-girt condition, loudly proclaiming the occasion for a great man; yet it was a long time before he came to liberate them. He appeared only in the last century to the city of London after that town had overflowed its bridges for generations, and he presented a scheme for driving a tunnel under the Thames through the comparatively soft clay. Everybody knew that so large a hole as a tunnel could not be dug and kept open under the Thames; but if a short, portable piece of completed tunnel could be continuously pushed ahead and added to from behind, what then? He conceived a steel contrivance just a trifle bigger around than the tunnel was to be, shaped in about the proportions of a baking-powder can, with no bottom and no top, but having a diaphragm or partition across the middle of it. When this had been sunk down and started on the line of the tunnel, the forward part of the shell would hold up the overhanging mud sufficiently so that men could work through little doorways in the partition, digging the earth from in front and loading it into cars to be carried out behind; and at the same time, on the interior of the after portion, other men could bolt together the steel or iron sections of the tunnel lining.

A short section having been completed in this manner, the whole machine could push itself ahead with a kick—that is, with powerful hydraulic jacks pressing against the completed part of the tunnel. Imagine having forced a large, empty sugar barrel horizontally into a bank of earth, first having knocked out both heads. By crawling into the barrel a man could, with considerable discomfort and perspiration, dig away the earth some little distance in advance of the barrel, and, given something to kick against, he could push himself and his barrel farther into the cavity he had dug. Now, if another man were to hand him the necessary staves and *internal* hoops, he could build a second and slightly smaller barrel partly inside of the first one. He might then do more digging and more pushing ahead, until he had proceeded far enough to build a second small barrel and fit it tightly to the end of the first small barrel. In this way, since a small barrel always lapped partly inside of the big one in which he worked, the earth could never cave in and cut him off from daylight; and so long as he was provided with staves, hoops, food, water, and air, he could burrow on indefinitely.

Such, in a nutshell, was the idea of a certain web-foot engineer, Sir Marc Brunel, in 1824—the simplest, best, most ingenious idea that has occurred to engineers in many years. The great cities had waited for it so long that they accepted it ravenously. Tunnels burrowed under the Thames, the Seine, the Hudson. Poor old tunnels that had set out without it and gone bankrupt at the discouraging rate of a few inches a week, took on a new lease of life and set out again at many feet a day; and they are going yet—all day and all night, steadily, blindly, but surely, on under the rivers to set the cities free.

Of course the original idea has to be modified somewhat for every particular tunnel and for each variety of mud. If the mud is full of gravel and boulders, the forward half of the machine has to be worked under compressed air to balance the pressure of earth and water; and the workers have to be provided with safety locks in case of a sudden inrush of water. If you invert a glass in a bowl of water and press it down, the water will not rise to any extent in the glass. On this principle, little inverted steel pockets are made for the men to retreat into in case of accident and keep their heads above water until assistance can come.

If, on the other hand, the earth is tough and regular instead of being dug out by miners the way is cut automatically with a large rotary cutter. If it is softer still and too mushy to be counterbalanced by compressed air, then the top of the forward shield is made very long, so as to let the mud cave in on a long slant and still not fall from above. When it gets to the consistency of porridge, as it is at the bottom of the Hudson, it is found possible to force the shield ahead without any digging, merely letting the mud ooze through the partition doors and shovelling it into the cars. At times it was thought possible to force ahead without opening the doors at all—merely pushing the mud out of the way; but this was too simple to be strictly according to the rules of the game, and the obstacle presented itself that the extra weight of this overcrowded mud was enough to lift or float the whole tunnel up out of its proper alignment.

Again, in the Boston tunnel, the mud was so accommodating as to stand up almost without support, so that the whole machine was reduced to a simple steel arch on rollers without any partition at all.

Another of the web-foot engineer's problems—to support a great weight on or over mud—would seem to be simpler than the under-water tunnel problem; and, up to a certain limit, it is. If the soil is capable of holding only one ton on each square foot, and a certain column is to sustain five hundred tons, all one has to do is to spread out its base by criss-crossed steel beams and concrete slabs to the extent of five hundred square feet—if one has the room; and if the adjoining columns are close enough to it so that their bases touch, you have your structure floating on one continuous slab. Nothing could be simpler or easier—unless some other man with an equally heavy structure to support comes to excavate a foundation alongside of yours, and the mud runs out from under you. I was once talking with a well-borer in Boston who put down wells, elevator-rams, test holes for engineers, and so on. He probably knew more about the underground condition of his town than any other citizen. "If," said he, "I were ever called on to lay siege to Boston, it would not be with guns, fire, or dynamite. I should simply sink a pit down near the Post-Office, where John Winthrop's spring still shows up, install a big pump, and begin sucking out the quicksand. In about two days every large building in town would be a wreck." And so it undoubtedly would be.

This brings us to the ancient expedient of pile-driving. Many thousands of years ago the more ingenious and weaker part of the population of central Europe maintained itself against the more warlike and less mechanically skilful part by building itself pile villages out over the lakes. And the stumps of the piles on which Cæsar crossed over the Rhine are still to be found, in proof that his luminous Commentaries are not fiction; yet, even in this late day, the science is still young, and every few months bring forth an improvement in the making and driving of piles. In fact, so perverse and unexpected is the behavior of piling that I doubt if it can ever be reduced to a science. For instance, you may drive a ninety-foot pile into soft river mud so easily that it will fall of its own weight to a penetration of twenty or thirty feet, and go indefinitely two or three feet to the blow of a fairly heavy hammer; and, having driven it, you may immediately hook a line to it and pull it out again. But allow it to remain driven for an hour or so, and you may sink a forty-ton barge and break every line in your outfit trying to budge it. Similarly you may pound for an hour on the unfortunate head of a pile that penetrates quicksand. A horse or a man could not stand for a minute on the spot without sinking out of sight; yet the pile, as if being driven on a rubber buffer, will bounce stubbornly under every blow, but sink scarcely a hair's breadth. Moreover, having, in the course of a long and discouraging day, succeeded in getting two or three bents down to a minimum depth, you may return next morning to see your whole day's work floated up and out during the night and idly sunning itself on a sand-bar a few miles downstream. Yet if you were wise enough to run a long pipe down by the pile as it was being driven, and keep a stream of water forced down through it to bore away the sand, you would find, immediately on withdrawing the pipe and stopping the water, that the pile was stuck fast, there to remain forever. Nobody knows how much a pile of given length and girth will bear till he tries it; but the holding power as compared with any spread-out surface footing is enormous.

It unfortunately happens, however, that although a sound stick of timber will remain such in thoroughly wet earth for ten thousand years, it cannot be trusted to last ten years in dry soil. Furthermore, if it stand in salt sea water, that harmless-looking but very costly long white worm, the teredo,—which, although neither ugly nor venomous, wears a boring-mill on its head,—will certainly make short work of it. Ten months in temperate water is all he needs to make honeycomb of the best stick of pine that ever grew.

To prevent this destruction and decay, then, it is obviously necessary to stop all timber work underground, below the possibility of dryness; and this is what takes most foundation work out of the hands of the top-soil contractor and places it in the hands of the web-foot. There is always some place in New York, and most other large cities in America, where he is to be seen making day and night and the neighboring property hideous with his smoking, pounding drivers and creaking derricks. First you see him taking great pains to build himself a water-tight dam of driven planks (he refers to them as sheet piling) or steel staves. Then come his bulky timbers as thick as a man's body, blocking the streets temporarily; and after these are placed, his ravenous bucket begins to bite out the dirt from the inclosure. Then his driver pounds down the piles that are to do the supporting of the piers, forcing them below the water, and driving them still farther with another short pile mounted temporarily upon their vanished heads. After this he has the choice of pumping out the water and sawing them off evenly, or of rigging a buzz-saw on a long vertical, revolving shaft to cut them off under water. He has a like choice in placing his pier upon their heads. With the water pumped away, he may make a dry-land job of it; or, leaving the water standing, he may lower the concrete in specially constructed buckets that remain tight until they touch bottom and then accommodatingly dump their cargoes without allowing them to be washed away; or he may drop all the concrete down through a steel or canvas pipe moved about over the pile-heads, or deposit it sewed up in bags. New Yorkers who habitually passed the site will remember seeing these piling and capping operations going on to make foundations for the then heaviest and tallest Park Row Building.

All these processes are delightfully simple to write down, but gray hairs and insomnia lurk in their actual doing. I once developed slight symptoms of this sort over a project—the building of a line of piers through a marshland where a railway crossed a slough that promised some day to be dredged out and made navigable water. On account of the modest shell-headed worm, piles had to be cut off thirty-five feet below tide—which meant about the same distance below ground. Everything went beautifully. The sheet piling went in like a gimlet into cheese, the big buckets ate up a yard of mud a minute, and the discharge water from the pumps sluiced it out to sea. Everybody was happy. But when the excavation was forty feet deep and the pile-driving began at that level, all happiness ceased. The very first pile that went down penetrated a limitless reservoir of quicksand. In an hour the pile had become the centre of a funnel-shaped crater another forty feet deep below the pit, from which spouted up tons of sand and water; and, in spite of all the pumping that could be done, the big excavation that had taken so many weeks to dig was full again. Moreover, having been undermined to the extent of what flowed into the excavation, the entire surrounding territory for a radius of a thousand feet began to sink. Down went the trestle and the track; down went the big derrick and rolled over on its side, steaming and sputtering in the mud. Down went all the sheet piling slowly into the water, till the sea rolled in over its top; but the cracking and bursting of the great struts within could still be heard as the splinters came floating to the surface. I have never seen a more disheartening wreck. It seems to me the imagination can never grasp the meaning of such a phrase, for instance, as "one hundred tons," nor grasp the immensity of the powers of earth and water, till he happens to upset their equilibrium and see them working in ponderous relentlessness against him.

But were the pier-builders in this instance discouraged? Not at all. They immediately despaired of making any money on the project, but not at all of finishing it. They diked off the sea, they set up and hosed off the derrick-car, began slowly lowering the water and replacing the broken timbers so far as they could; and then allowed the pit to flood again. Then, with the weight of the sea water in the pit to counterbalance the quicksand, they dug blindly and slowly through the water. The sand held; and taking courage at this, they began again to drive piles. Everybody watched breathlessly the first pile to see if the sand would again gush forth; but the weight of the water continued to hold it. So the piles were driven as the digging had been done—patiently and blindly through water. Once the "follower" pile slipped so that the great hammer struck down on nothing and the tall driver fell in a heap of kindling-wood, and the top man was carried away to the hospital; but they rebuilt and went on. Then came the diver in his helmet and leaden shoes to go down and cut off the piles at the right level. This was the most expensive process to the builders, but the most interesting to the onlookers; for to sit on the dike and watch the long pile-heads emerge miraculously from the deep and leap like porpoises in the air was more fun than a cock-fight. Finally came the filling with concrete through the long pipe until enough solid concrete had been placed to equal the weight of water. Then the water could safely be pumped out and the worst was over.

This being merely a sample of the many difficulties of web-foot operations, it is small wonder that many schemes are afoot to make piles of concrete so that they will not have to be cut off at such low levels. A look at the advertising pages of any engineering magazine will show that much gray matter is being expended now in that direction. There are concrete piles that are driven by first driving a steel pile surrounded by a thin steel skin. The pile is pulled out again, leaving the skin to be filled with concrete. Others are made by driving a pipe with a steel point and then pulling it up. As it comes up, the steel point opens like a walnut, so that concrete can be rammed down through it to fill the hole. And there are piles that are moulded in boxes above ground and driven like wooden ones, save that the water is jetted down through a pipe in the middle of them. But all these have their disadvantages. Who can say, when a pile is made underground, that it is perfect? Who can say, when a pile is driven, that it is not cracked? Who can say why the famous concrete piles in Baltimore Bay are rotting at the water's surface? Concrete of the modern reinforced variety has been the cause of more bitter disappointment than any material we use. It will be difficult indeed to find a substitute for that good timber that Mr. Pinchot is so anxious for us to save, and that, when properly placed, will remain sound after steel is rusted, and concrete is crumbled, and gold itself is tarnished.

It will easily be seen that piling of any sort has its limitations. Supposing the Boston well-borer to be correct, then, if such a pit as we have described were dug in any city, obviously the whole neighborhood would fall into it were it not based on unyielding ground.

Foreseeing this possibility and its consequences, Mr. F. H. Kimball had the commendable obstinacy to insist that the foundations of the Manhattan Life Building in New York should go down to solid rock. Notwithstanding much adverse criticism at the outset, his idea was finally accepted so completely that, during the following fifteen years, New York became the greatest deep-foundation city in the world. Nowhere else do men go dry-shod eighty-five feet below water-level without intervening barrier—as they did under the Mutual Life Building—and come back to tell about it. Nowhere else do caissons sink at the rate of two feet an hour, as they did on the sites of the North Trinity and United States Realty buildings. Nowhere else does one come upon complete portable air-compressing plants that will stand carting about a city, and when set down are capable of sucking in, compressing, and cooling a column of air a foot square at the rate of forty-five miles an hour. The New England coast has its six- and seven-masted schooners; but New York is the only known cruising-ground of the four-masted, four-boomed, electric-driven, rapid-hoisting, self-turning, portable derrick.

The colossal mistake by which New York was originally located is now of incalculable value to our engineering profession; the fact that it stands upon an island several sizes too small, surrounded and partly overlaid by sixty feet of mud, has developed more real engineers in America than all the technical colleges that we have.

In the caisson, as elsewhere in engineering, we find the principle foolishly simple, but the exigencies by the way both dangerous and difficult. Imagine a circular steel chimney, having two air-tight dampers in the middle of it, to be stood on end in soft ground. Obviously its weight, resting on its thin edge, would force it down like a pastry-cutter through dough. If, then, a man got into its interior and began digging and passing out the dirt in buckets or sacks, he could continue to lower the earth level inside and the chimney would continue to sink; but after three or four feet the water, which he could not remove faster than it ran in, would bring him to a halt. Now, a column or a stick of water an inch square and a foot high weighs about half a pound. Therefore, if air were pumped into the chimney below the dampers until it pressed half a pound on every square inch of it, the water would subside one foot; if five pounds, ten feet; if fifty pounds, one hundred feet, and so on. The earth could be passed or hoisted out past the dampers without allowing the air to escape, just as a boat passes through a canal lock without wasting more than the lockful of water. But the unfortunate "sandhog," the crouching, sweating digger of earth inside the chimney, is seldom found who could stand fifty pounds of air on every square inch of him, inside and out, and there is the difficulty.

There are other difficulties. Suppose the air-pressure more than counterbalances the chimney—the caisson; then tons of iron or concrete must be piled on it to sink it; sometimes it is possible to use the future pier for this purpose. Suppose the air more than balances the water and blows out, causing a leak and the sudden imprisonment of Mr. Sandhog. Suppose, on the other hand, that through the breakage of a pipe or the explosion of a cylinder, it falls below normal. There again is danger. It is all danger, in a way, until the caisson is safely down on hard rock and filled with concrete. When we arrive at a habitable structure like the Metropolitan Tower, seven hundred feet high, standing ankle-deep in sixty feet of mud, with nearly four thousand tons bearing on every ankle, we see that man is "monkeying" with weights and balances so enormous that they outrun his imagination. Mathematics is his only medium for arriving at them.

More baffling still, the constitution and endurance of Mr. Sandhog himself can not be scientifically determined. He may, at any moment, with the pressure of three additional atmospheres upon him drop with heart failure, or be struck with paralysis, or come out of his caisson, after a brief hour and a half's work, stone-deaf for the rest of his days. All miscalculations, oversights, accidents, and blunders in this business are payable in human life. No large undertaking of this sort is without its tragedy, and one has but to stop and read the familiar little tablet on Brooklyn Bridge to be set thinking of the prices we have to pay for the things we have to have.

Yet, notwithstanding the difficulties encountered by the way and the very rapid development of his art, the modern web-foot has carried on his operations so scientifically that to-day we have the astonishing but perfectly sane statement of Mr. O. F. Semsch, the designer of the Singer Building frame, that, given a lot two hundred feet square *and* the trifling sum of $60,000,000, he could erect a building or tower two thousand feet high which would stand perfectly firm against sinking or blowing over, and be well within all the building ordinances of the city.

In order to appreciate the great jump-off from ancient custom that had to be made in order to accomplish these things, we need take only the most superficial glance at the older structures. The Pyramids are securely founded on high and dry rock; therefore above reproach. Most of the Roman edifices are also on hills. The Tiber, being an intermittent stream, enabled the Romans to build a few good bridges during dry seasons; but the Forum, being on marshland, is an engineering botch, and the Cloaca Maxima so persistently apt to get stopped up that for hundreds of years the whole works were abandoned and used for a dump. Going a little further, we have the leaning towers of Pisa and Bologna, not to be compared in weight to a large modern factory chimney, yet able to show us how lamentably weak the old fellows were the minute they got a bit bogged; and in Venice we see the most striking example of how an entire city, although beautifully architectured, was never properly foundationed.

The costly buildings of Chicago, standing on shallow grillage and sinking so many inches a year, serve to emphasize at what a late date builders still hesitated to venture into the unstable depths.

Considering, then, the courageous jump-off from all precedent and established custom that the web-foot engineer has had to make, it is not surprising to find that the "father of civil engineering" in modern times was himself a pioneer web-foot. John Rennie was originally a mill constructor. But when the tide washed the foundations out from under his mills at Blackfriars

Bridge, he was forced into matters of a larger sort. He earned his title by draining off that part of England which the appropriately named River Ouse had made into a hopeless swamp (a job that baffled even the great Cromwell), thereby furnishing the first and best example of the web-foot's third problem, wherein, by a system of dikes and ditches, he "un-waters" the land and renders it fit for cultivation. The magnificent Waterloo Bridge across the Thames is also his work,—his monument,—and when one looks upon this and the adjoining massive structures, which better than anything else portray the true solidity and grandeur of the English people, it is hard to believe that they are all standing knee-deep in river mud.

Rennie has his engineering descendants in every large modern city—in almost every large project of any kind; but especially are they to be found in our tallest, heaviest city of all—men far more worthy to be proud of than the world's records they have broken, or the inventions they have made: Mr. J. T. O'Rourke, who proposed the first circular caisson and invented a way to remove the roof or partition immediately over Mr. Sandhog's head so as to render the concrete pier one solid piece instead of two; Mr. John W. Doty and Mr. Daniel E. Moran, who simplified it further, making the future concrete pier serve to sink itself and arranging trap doors of such lightning action that the bucket and its muddy contents make a trip every minute; Mr. T. Kennard Thomson, who designs the four-masted derricks and whom I suspect of having everything to do with the speed records made in sinking caissons; Mr. Alfred Noble and Mr. Charles M. Jacobs, under whose supervision the East River and North River tunnels were designed; Mr. Samuel Rea, who passed upon all the plans, and directed the entire work; Mr. E. W. Moir, who personally supervised its execution; to say nothing of the assistants and resident engineers—Harrison, Brace, Mason, Woodward, Japp, Manton, who "slept on the job," worried over it, perspired over it, dreamed of it in whatever sleep they were fortunate enough to get. It is they whom I have respectfully termed web-foot engineers, who have transformed a small river-girt, rock-backed, swamp-covered, scarcely habitable island, originally worth twenty-four dollars, into what is now, in some respects, the most livable, though in other respects the most unlivable, but at all events the most lived upon, most densely populated, richest spot under the sun.

INTERURBAN ELECTRIC TRACTION SYSTEMS; ALTERNATING CURRENT VS. DIRECT CURRENT[1]

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[Mr. Lincoln's paper is a good example of a frequent type of technical exposition, the comparison. This type, as in the present article, usually takes the form of an argument in favor of one side of the two or more presented. Expository elements to be noted here are: (1) the use of numbers and subtitles to mark the various divisions of the paper; (2) the fairness with which the claims of the other side are met and the methods by which they are disposed of; and (3) the concrete presentation at the end of the paper of typical cases with comparative series of curves and tabular comparisons. In reprinting, these curves and tables, together with the comments on them, have been omitted.]

Practically all the electric railway work in America has been done by direct current. The alternating current traction system, although it has received considerable attention from American engineers, has not until recently been favorably considered by them. In Europe, on the other hand, the alternating current traction problem has received a large amount of attention. The polyphase induction motor has been developed by European engineers for traction purposes and a number of installations have been made in Europe with apparatus of this character. American engineers have consistently refused to adopt the polyphase induction motor for traction purposes on the ground that it is not suitable for that purpose. The principal reasons for this stand are two in number.

First, the polyphase induction motor is inherently a constant speed motor and therefore not adapted to traction purposes. Con-

[1] A paper read before the Electrical Section of the Canadian Society of Civil Engineers. Reprinted from the *Engineering News* for December 17, 1903 (Vol. 50) by permission of the publishers.

tinual change of speed is one of the characteristics of traction work. The direct current series motor is peculiarly adapted to this class of work because it is inherently a variable speed motor. At one definite speed the polyphase motor is an efficient machine, while at all other speeds the efficiency cannot be greater than the ratio of the actual speed to the synchronous speed. For instance, if the actual speed at which a given induction motor is working is 10% of its synchronous speed, the power utilized is at most only 10% of the power put in. In traction work a large part of the work done is necessarily at speeds below the maximum attained, and at these lower speeds the maximum economy that can be obtained from induction motors is necessarily small.

One expedient used by European engineers to reduce this source of loss is the use of motors in concatenation or in tandem; that is, the secondary of one motor is fed into the primary of another on the same car. If the pair of motors thus concatenated are wound for the same number of poles, this expedient has the effect of making the synchronous speed of each of the pair of concatenated motors half that which it is when not in concatenation. It is equivalent in direct current practice to throwing two shunt motors in series. Up to the half-speed point, therefore, there is a gain of economy by this arrangement. By winding the two concatenated motors for different numbers of poles, more than one point of maximum economy can be secured between zero speed and full speed, but this arrangement has the disadvantage of being able to use but one half the total motor capacity above half speed, while the greatest expenditure of energy takes place above half speed. In order to secure the advantage of concatenation, however, it is necessary to add largely to the weight of the electrical apparatus. European practice has been to equip cars with four motors, two main motors and the other two being used only while the car is below half speed. Above half speed these latter two motors are running idle and are doing no useful work. The energy required to take care of the additional weight is an offset against the energy which is saved by concatenating the motors. For long runs this expedient would probably be detrimental since the energy taken up to transport the extra weight would be more than equivalent to the energy saved at the start.

The second reason against the use of polyphase induction motors for traction purposes is the necessity for providing at least two overhead conductors. If the track is not used as one of the conductors, then the necessity arises of using at least three overhead conductors. Maintenance of insulation on such overhead conductors when they are at high voltage is naturally a difficult problem, more difficult than to maintain the insulation between a single conductor and ground, as would be the case in the single phase system.

American engineers, instead of endeavoring to adapt the unsuitable induction motor to traction purposes, have devoted their energies to the development of a suitable alternating current motor. The idea of using a series motor operated by alternating current is not new. The only alternating current single phase motors which have speed and torque characteristics suitable for electric traction purposes are those of the commutator type. In this type of alternating current motor the speed and torque characteristics are practically identical with those characteristics in the direct current series motor. Interurban electric traction work, such as exists to-day, was not at that time thought of, and this is, in my opinion, the field peculiarly adapted to the alternating current traction system.

In considering the general problem of electric traction, the question naturally arises—what is gained by the use of alternating current over direct current? And the converse of this question naturally arises—what is it necessary to sacrifice in order to obtain the benefit of alternating current traction?

The principal advantages of the alternating current electric traction over the direct current are as follows:

(1) Limits to trolley voltage are removed.

(2) Avoidance of rheostatic losses.

(3) The necessity for rotary converter sub-stations abolished.

(4) Manual attendance at the sub-stations done away with.

(5) Danger of electrolysis by return current avoided.

To take up these points more in detail:

(1) Voltage Limit Removed.—The greatest item of cost in the electrical equipment of interurban traction systems as they exist to-day is that of secondary distribution. This item of cost is usually between 25% and 50% of the total for electrical equipment, and usually much nearer the latter figure than the former. A potential of 600 volts at the motor in a direct current traction system is practically the limit at which present designers and manufacturers are willing to guarantee their machines, except in some

special cases. This necessarily limits the voltage fed into the secondary distribution system to, say, 700 as a maximum. The consequence of this comparatively low voltage is naturally a high cost for conductors of this secondary distribution. The alternating current system, providing as it does the possibility of greatly increasing the voltage of the distributing system, thus largely cuts down its cost.

Another point which militates against the use of direct current is the fact that when large units are used it is difficult to collect the large amount of current for their operation. For this reason, as well as an advantage in cost, trolley construction has been largely replaced by the third rail for interurban work. By raising the voltage of the secondary system, however, the current taken by a locomotive may be reduced and consequently the difficulty with collecting devices may be made to disappear.

(2) Rheostatic Losses Avoided.—In the direct current system the voltage at the car is practically constant and while the counter E.M.F. of the motors is building up, the excess voltage must be taken up by resistance. At the start, therefore, a comparatively large rheostatic loss occurs. With the alternating current system, on the other hand, the voltage at the car may be controlled by suitable means, and the rheostatic loss thus avoided. When stops are few and consequently runs are long, the rheostatic loss in the direct current system is a small proportion of the total, and therefore under these conditions this advantage of the alternating current system is not so greatly marked. With short runs, on the other hand, and consequently frequent starts, the rheostatic loss with the direct current system amounts to a considerably greater proportion of the total loss and the alternating current system therefore has a greater advantage.

(3) Necessity for Rotary Converters Avoided.—The cost of sub-station equipment constitutes one of the large items in the cost of the electrical equipment of an interurban road. In this sub-station equipment by far the largest item of cost is the rotary converters. In the alternating current equipment the rotary converter has no place, thus avoiding not only a large item of cost, but also one of the largest items of the loss of power.

(4) Attendance at Sub-stations Done Away With.—The direct current rotary being a piece of revolving machinery, of course requires manual attendance at the various sub-stations. Alter-

nating current sub-stations consist of static transformers only, and therefore require attendance only for the purpose of operating the switches. Making the switching devices entirely automatic in their operation avoids the necessity of attendance for this purpose. A still further refinement is the use of distant controlled switches operated from a central point, say the main power house. Electrically operated switches have already been developed to be operated from a distance of several hundred feet, and no reason exists why this distance of operation cannot be extended to 20 or 30 miles by proper design. By including in such a switch-operating mechanism also a signaling device, by which the position of the switch is made known at the central point, the switch-operating system becomes complete and no necessity exists for attendance at the alternating current sub-stations for any purpose except occasional inspection. There is, of course, an expense in connection with installing such a system of operating switches electrically, but it bears no comparison to the expense of manual attendance.

(5) Electrolysis.—Electrolysis of parallel conducting systems is generally recognized as one of the most serious dangers in connection with present direct current trolley systems, and the fact that an alternating current system avoids this danger entirely need only be mentioned in order to be recognized as a marked advantage.

So much for the advantages which accrue to the alternating current system. Now the question arises—what points must be sacrificed in order to obtain these advantages? The disadvantages which necessarily accompany the use of the alternating current system traction system are as follows:

(1) Additional weight.

(2) Difficulty of operating on existing lines.

(3) Increased rail loss.

(4) The fact that an active E.M.F. exists between field turns.

(5) Possible interference with telephones.

We will take up the above points in detail.

(1) Additional Weight.—An alternating current motor of a given capacity is necessarily somewhat heavier and somewhat more expensive than a direct current motor for the same capacity. This difference in the motor, however, does not constitute the total difference in weights of equipment. In order to make use of the advantages of high trolley voltage, the alternating current equipment should preferably be provided with a step-down transformer

on the car. Also, in order to obtain the advantage of avoiding the rheostatic losses, some provision must be made for controlling the voltage on the car. The transformer, the voltage control apparatus, and the greater weight of motors make the alternating current equipment necessarily heavier than the direct current.

One of the most attractive methods for controlling the voltage on the motors is the use of an induction regulator. The principal advantage over other forms is that it does not require the interruption of the current and is therefore of particular advantage in large equipments. It is this problem of breaking the current that forms not only the greatest difficulty with direct current equipments of large capacity, but also one of the largest items in the deterioration account. The induction regulator has the disadvantage of adding considerably to the weight and in equipments of comparatively small size where the difficulty of current interruption is not great will probably be replaced by some other method of voltage control, such as loops or commutated coils on the step-down car transformers.

(2) Difficulty of Operating on Existing Lines.—Practically all interurban roads run in and through cities on existing tracks, and therefore, must use the existing sources of direct current power. In order to meet this condition the equipment for an alternating current interurban road must be so arranged as to operate on alternating current outside the city and on direct current inside. Although this is entirely possible, it must necessarily prove to be a matter of considerable complication. It means in the first place the use of motors which can be operated from both direct and alternating current. This is entirely possible with the series alternating current motor. It means in the second place that another system of control must be added to the car. This objection might in part be avoided by using rheostatic control for both the alternating current and direct current conditions, but the objection obtains that this method will deprive the alternating current system of its advantage of saving rheostatic losses. Further, means will have to be provided for disconnecting all transformers when running from direct current system and reconnecting them when running from alternating current system. All these matters, although they mean a considerable amount of complication, are entirely possible. The most important part of the equip-

ment—the motors—can be operated from direct as well as alternating current.

(3) Increased Rail Cost.—Experiments have shown that with alternating current from 2,000 to 3,000 alternations, the actual loss which takes place with a given current through the iron rails is from three to five times that which the same direct current would give. The higher ratios of loss hold for the higher frequencies. At first thought this seems to be an important objection to the A.C. system. But when it is considered that in order to utilize the main benefit of the alternating current, a higher trolley voltage is used and, therefore, smaller currents in the return conductor, the element of rail loss in an alternating current proposition may be made even a smaller proportion of the total than in the direct current in spite of the apparently large handicap. The rail loss with direct current is usually a small proportion of the total and this with alternating current, at the trolley voltages which are usually considered—viz.: 2,000 to 5,000—becomes a much smaller proportion.

(4) Active E.M.F. Between Field Turns.—The space that can be assigned to the motor for operating a car is necessarily limited. It is this limitation of space, in fact, which often forces the use of a four-motor equipment instead of a two-motor equipment, the available space not being large enough to allow the installation of motors two of which are sufficient for the work. When we consider the A.C. motor, the question of space available becomes still more exacting, first because the A.C. motor is necessarily heavier and therefore occupies more space than an equivalent D.C. motor; and second, because of the active E.M.F. that exists between the field turns in the A.C. motor, and which, other things being equal, again requires additional space for insulation. In the matter of E.M.F. between field turns, the A.C. and D.C. motors are quite different. The E.M.F. between the field turns of a D.C. motor is due simply to ohmic resistance, and a short circuit between turns simply throws out of action the turns so short circuited, and if not too severe, does not interfere seriously with the motor's operation. Between field turns of the A.C. motor, on the other hand, there is an active E.M.F. similar to that between the turns of a transformer winding. A short circuit between field turns in an A.C. motor, therefore, means a destructive short circuit and an immediate interruption of service from that motor. In other words, the effect of a short circuit between the field turns in an

A.C. motor has the same effect that a short circuit between armature turns would have in either the A.C. or D.C. motors. Roasting out of field coils is one of the most frequent causes of trouble in D.C. motor equipments, and it is readily realized that this matter of active E.M.F. between field turns in the A.C. motor is a serious one. As an offset against this disadvantage of an active E.M.F. between field turns, the A.C. motor possesses the advantage of being capable of operation at low voltage, thereby reducing the number of turns on the series field and increasing the proportionate space for insulation. The use of a step-down transformer on the car makes available any desired voltage at the motor. This existence of an active E.M.F. between field turns is the most serious obstacle to the use of high voltage on the motor. Even with low voltage, the A.C. motor is laboring against the handicap of occupying more space than an equivalent D.C. motor, and the use of high voltage still further increases this handicap. The limitations of space do not apply to the transformer in anything like the same degree that they do to the motor, and no particular difficulty is anticipated in building a transformer for this work.

This limitation of available space for the motor and the existence of an active E.M.F. between the field turns make it seem probable to the writer that the A.C. railway motor of the future will be operated at low voltage and will receive its current from a transformer situated on the car.

(5) Interference with Telephones.—It is a question whether alternating current in the rails will interfere with telephones and similar instruments more than the direct current which they have to contend with at present. In any event, the amount of current in the rails can be reduced by the use of higher voltages so that this source of interference can be made less than it is with the present direct current system. Further, means have been proposed whereby the current can be confined entirely to separate conductors provided for the purpose and not allowed to wander at will through any return circuit that may exist, as is the case with the direct current system. This can be done of course only at the expense of erecting a separate system for the return currents and a system of series transformers whereby these currents can be confined to this return system. The alternating current system, therefore, possesses the advantage of being able to use the rails for contact and still not allowing the alternating currents to escape at will

through the earth. As a matter of fact, interference with other circuits by the alternating current system is expected to be less than with the present direct current system.

The engineer has been defined as a man who could do for one dollar what any fool could do for two. The engineer, in other words, stands for efficiency. It is he who accomplishes a given result with a minimum expenditure of effort and money. Suppose we apply this criterion to the comparison between the A.C. and D.C. systems: by which of these systems can a given service be rendered more economically? In order to answer this question, we shall assume a certain typical interurban road, ascertain the first cost by both systems and the cost of operating by both systems and compare the results. Suppose the typical road which we will assume to be as follows:

Length—60 miles.

Schedule speed—30 miles per hour, cars running half hour apart.

Number of stops—30; that is, typical run, 2 miles long.

Weight of D.C. car complete, 35 tons.

Weight of A.C. car complete, 41.3 tons.

[Mr. Lincoln's paper concludes with two figures which show respectively the speed-time and KW.-hours curve of a direct-current car of 35 tons over the typical run described, and the same, together with the apparent KW. and power factor, for an alternating-current typical run, and an elaborate series of comparative tables showing power consumption, power losses, first cost, and operating expenses for both systems, with notes on this tabular comparison.]

Telephone Service in America[1]

By John J. Carty, Chief Engineer

American Telephone and Telegraph Company

[This is an excellent example of a type of technical exposition frequently encountered, the convention or conference address on a professional subject under dis-

[1] Privately printed. Suggested by Mr. M. C. Rorty of the American Telephone and Telegraph Company, and reprinted by generous permission of Mr. Carty.

cussion. Some good things to be noted about the article are: (1) The clear introductory statement of the aim and scope of the paper; (2) the refusal of the writer to accept at their face value the principal technical terms, *automatic* and *manual*, involved in the discussion, and his clear analysis of those terms; (3) the convincing climactic arrangement of evidence against the so-called automatic switchboard; (4) the careful transitions and frequent division summaries, more necessary in an address than in a printed article; and (5) the establishment at the conclusion of the writer's claim to a scientific judgment unbiased by selfish ends.]

In the Discussion on Automatic vs. Manual Switchboards at the International Conference of European Telephone and Telegraph Administrations at The Sorbonne, Paris, September 4th to 11th, 1910, Mr. Carty said:

Mr. President and Gentlemen:

In response to your request I shall speak upon the question under debate. I will tell of conditions in America, with which I am personally familiar, and regarding which I have accumulated data covering a period of years. I do not presume to speak concerning conditions in Europe, so that I shall be obliged if you will regard what I have to say in this light. From your own expert knowledge of conditions in Europe, each of you will be able to judge how far the experience which we have obtained in America may be applicable to your own case.

The subject under discussion is sometimes stated as "The Manual Switchboard System versus the Automatic Switchboard System." It will be instructive to see what is meant by these two terms.

The term Manual Switchboard denotes a system whereby the operation of connecting two subscribers together is performed by hand, and without the employment of automatic machinery.

The term Automatic Switchboard, on the contrary, denotes a system whereby the two subscribers are connected together by automatic machinery and without the employment of manual labour.

I shall ask you to consider with me for a few moments these two systems.

Let us begin with the so-called Manual Switchboard and make a brief analysis of its method of operation, and by so doing we shall find that it abounds in automatic features and that in its operation automatic labour-saving machinery has been employed to an extent which is truly surprising to anyone who makes the analysis for the first time. You will find that the term Manual does not correctly describe the system to which it is applied, and that the so-called Manual Switchboard System is partly Manual and partly Automatic, and you will find that the number of automatic operations which take place in making a connection form a large proportion of the total.

It would consume too much of your time if I should describe in detail each of these operations which is performed automatically and each which is performed manually. I shall give a brief outline of them, and when once your attention has been drawn to this phase of the case, you will have no difficulty in making the complete analysis at your own convenience.

The subscriber desiring to make a call first takes the telephone from its hook and places it to his ear. This is a manual act, but one which is necessary in every system. Removing the telephone automatically releases the hook which flies into contact with several springs, the result of which is to set in motion a train of automatic apparatus closing the subscriber's circuit at the sub-station thereby automatically actuating a relay at the central office. This relay having been automatically set in operation lights a lamp before the operator, who thereupon performs a manual act, inserting the plug into the answering spring jack. This again automatically makes connections, which accomplish a number of different operations, such as disconnecting the line relay, and so forth. The operator works her listening key and connects to the called-for subscriber. This causes a train of automatic operations to take place, and then the subscriber's bell is rung. He takes the telephone from the hook, and this automatically notifies the operator that he is at the telephone.

The reverse of all this takes place when the disconnection is made. The subscribers hanging the telephones on their respective hooks thus set in motion a complex train of automatic operations, whereby the operator, without listening in upon the line or asking the subscribers if they are done talking, may determine at a glance that the conversation is finished, and by the simple operation of withdrawing the plugs and allowing them to fall automatically into their positions, mechanism is released which automatically restores the lines to their original condition.

In the handling of trunk calls, i.e., calls between the "A" operator and "B" operator in the different offices, another extended series of automatic operations are intermingled with those which are performed manually. In fact, a complete analysis of all the operations involved will show that a very large proportion of them are performed automatically. Thus, it will be seen that notwithstanding what may be said by the partisans of the so-called Manual system, they have, by their deeds, acknowledged that there are many advantages in automatic machinery; in fact, if we trace the evolution of the Manual switchboard as exemplified in the modern Common Battery system, we shall find that its progress towards the present high state of efficiency is marked by the adoption of machinery to perform operations which, in the earlier systems, were done by hand.

In the old type of Manual systems, it was necessary for the subscriber, in order to signal the office, to turn a crank, thus operating the magneto generator and throwing a drop at the central office. At first it was necessary for the operator to restore this drop by hand. Then a plan of automatically restoring the drop upon the insertion of the plug by the operator was adopted. Finally, the drop itself was removed and relays automatically controlled by the subscriber and bringing into play at the proper time electric lights, were substituted.

A study of the growth from the earliest systems to that at present in use shows in a very interesting way that the high efficiency now obtained from the Common Battery System is largely due to the adoption of automatic operations. As it will be easy for anyone to make this analysis for himself, I will not pursue it further, but enough has been said to make it clear that the so-called Manual system is really one composed of both Manual and Automatic operations. It is partly manual and partly automatic. It is, indeed, a form of semi-automatic.

Turning now to the so-called Automatic System and making but a brief analysis of its operation, we find that properly speaking, it is not an automatic system, but only partly so, and that without the aid of human intelligence at the central office and without the employment of operators, it has not been possible to operate it on any substantial practical scale. While this is true even in a telephonic network with a single central office, the full force of the statement is not appreciated until we contemplate the so-called Automatic System as being applied to a comprehensive telephone system, such as sooner or later must grow up in every country and in every city.

Let us consider the operations of the Automatic System in the elementary case of a single central office. The subscriber desiring to send a call must take his telephone from the hook and perform a number of manual operations, depending upon the character of the call he wishes to send. Then he must press a button, which if all goes well, rings the subscriber desired.

It has been found in practice, however, that this automatic machinery at the central office can be made to give service only by the aid of mechanicians constantly in attendance there. The duty of these mechanicians is not simply to make repairs and remove faults in the ordinary sense of the term, for they do more than this. They actually assist the machinery to work. By the most careful training, some of them become exceedingly expert, so that with a supersensitive ear, they are able to detect when the machinery is going wrong. They are equipped with portable telephones and transmitters, and when they have reason to suspect that the call is not going right, they listen in upon the subscriber's line, and if the machinery has gone wrong, they ascertain from him the number desired and operate the machinery by hand, so as to produce the desired connection.

The assistance which they give requires them to listen frequently to the conversation of the subscribers and to give constant surveillance to the connections. This supervision is as varied as the character of the faults encountered.

These men, whose presence is essential to the working of the system, are, in fact, "Mechanician Operators." In addition to these, operators must be employed for toll and long distance work, for answering subscribers who call for numbers which have been changed, and for performing those large classes of service requiring human intelligence.

In America, wherever you go into an automatic exchange, so-called, there you will find operators employed for these various classes of service which I have mentioned, and for more which I might give in detail if time permitted. In all of these exchanges comfortable operators' quarters are to be found, together with the usual provisions of lavatories, retiring rooms and other conveniences which are to be found in the so-called Manual exchanges.

But it is not in the system in its undeveloped state employing only one central office that the Manual features of the Automatic system are to be most clearly discerned. In order to see how thoroughly misleading is the term Automatic Switchboard as applied to these systems, it is necessary to contemplate a telephone system more or less highly developed.

To do this we must consider the telephone system as a whole, taking into account all of the circumstances of the case, not simply one, or two, or three of them, but the whole multitude of factors which enter into such a complex problem.

We must give rigorous attention to a vast amount of data and requirements pertaining to the traffic upon which the design of the system is based, and we must take carefully into account all of those important commercial circumstances which have such a profound, though often unsuspected effect in broadly shaping the results.

It is only after we have done all of these things that we are prepared to begin to design the plant of the Telephone Company or Administration. This word Plant, which in the English language is applied to the structure constituting the physical property of the Telephone Company, is happily suggestive in connection with the point I wish to illustrate, for it brings to mind the idea of growth, and that in a problem such as ours, in order to attain successful results, we must contemplate a plant or system as it must exist at its different stages of development. We are not building something which, as it leaves our hands to-day, is in its final form. Each day, each month, each year, our plant is growing and we must so shape it, and so add to it, that as this growth proceeds it will have the highest efficiency which may be expected of it at each period of time. And above all, we must take care that the principles upon which this growth is planned will be such that when the system is fully developed, it will be working at its highest efficiency.

Our view is not comprehensive if it is confined to the central office switchboard alone. We must always have in mind, that while this is a vital part of the system, it is by no means all, and that considering the telephone investment as a whole, the money invested in central office switchboards is a relatively small part of the total.

In our American practice we have for years endeavoured, and I may say with substantial success, to take this view of the situation. In my office there is a large sub-department devoted to the study of the question from the standpoint of subways and cables; another for buildings; another for all telephone apparatus, including central office switchboards; another and very large department working upon the traffic parts of the problem; one devoted to development studies relating to growth of population and stations and kindred subjects; and still another whose sole duty it is to make fundamental plans based upon all of these data put together and co-ordinated.

These fundamental plans being based upon all of the factors in the case provide in outline for the location and number of the underground ducts and cables, the location and size of the central offices, and the size of the central office switchboards.

It is obvious that if to serve the needs of a given locality, it is necessary at the present time to put underground a single duct, it would be a mistake to limit our construction to the immediate needs of to-day, provided, as is nearly always the case, further growth is to be expected. Some provision for the future must be made. How many ducts, therefore, we should put down in advance of the immediate needs is a very important engineering and economic problem. If but one duct is put down now, and another one is needed the following year, manifestly a waste of money will be incurred, due to removing the pavements and making a new excavation the following year. To provide for the future, therefore, by adding duct by duct and digging up the streets each time a new duct is needed, would cause a great waste of money.

On the other hand, to take an extreme case, if a sufficient number of ducts were put down to provide for the needs of 100 years in the future (even assuming we could forecast correctly for such a long period), another waste of money would take place, for the interest and other annual charges upon the construction which must remain unproductive for so many years would more than offset the saving which would be made by avoiding the repeated excavations.

We must choose, therefore, in our construction, some point between these two extremes.

In the plans which we have made for New York and for the other Cities in America, it has been found, all things considered, most economical when building new subways to plan for a period somewhere between 15 and 20 years ahead. Such considerations as these have guided us in making fundamental plans for New York City, which so far as buildings and subways are concerned, are intended to form a general guide for our construction work which is to take place each year for the next 20 years. These plans are not speculative or paper plans, but we express our confidence in them by following them in the construction which we do each year, putting down not only that which is needed for to-day, but that which after most careful studies, represents our best judgment of what will be required during a period of 20 years.

It should not be understood, however, that we can forecast with precision the requirements for so long a period ahead, but we have worked with these fundamental plans now for so many years that we know that they form a trustworthy guide, provided that they are continually kept under review and modified each year as the exigencies of growth demand.

If it would not take me too far away from the subject under debate, I could show to you in many interesting ways the vast sums of money which we have saved because of these fundamental plans and how absolutely essential they are in enabling us to expend most economically the enormous sums of money which we annually put into our plant. For example, our expenditure for new construction during the first six months of 1910 is more than $21,000,000.

With such plans before us for a given city, we are able to study the probable conditions of the plant at each period of its growth, and with such a guide we are deterred from installing a switchboard or other system, however suitable it might seem to be at the moment, that would not be capable of growing into that form and to that magnitude which would be required of it by the conditions which it must encounter before its life has expired.

Some idea of these conditions at New York so far as they are affected by magnitude may be obtained from the following data. The fundamental plans for that city, not including the vast suburban region outside of the municipal limits of Greater New York, provided in 1900 for a system of 51,398 telephone stations, served from 43 central offices, the population of the city being 3,437,000.

In 1910 the plans provide for 376,000 stations, served from 52 central offices with an estimated population of 4,800,000. In 1930 the plans provide for 2,142,000 stations to be served from 109 central offices, with an estimated population of 8,800,000.

Without any commentary whatever these figures at once put us on our guard against the grave danger of assuming, even if the so-called automatic system was suitable for a small number of subscribers, that it would be a proper thing to employ in New York or any other city where it is expected that a proper development of the telephone will take place. This feeling of caution is strengthened when we consider that in the neighborhood of New York City there is a vast suburban region intimately connected with it telephonically and served by a very great number of central offices connected by a plexus of trunk lines. But there is more than this which we must take into account when we are studying this automatic system as applied to America. It is the grand ideal of Mr. Theodore N. Vail, the founder of the Telephone enterprise in America and still its active head, that we shall provide Universal Service. That is, that each person, firm or company in the United States that ought to have a telephone shall be provided with one, and that any person so provided wherever he may be located, can within a reasonable time be connected to the telephone of any other subscriber and talk satisfactorily.

This is not a mere dream. We have done solid continuous work upon it for more than thirty years and now with rapid strides it is proceeding to fulfilment. At the present time an enormous amount of toll line business takes place between New York City and the territory tributary to it for 30 miles around. In 90% of this business the connection is made in an average of 38 seconds, and in the remaining 10% the average is about 80 seconds. In all of these cases the transmission conditions are so planned that the subscriber may converse with ease. A local call is accomplished in less time, requiring only 22 seconds where but one office is involved, and slightly more between two offices.

These figures which I have given include the elapsed time from the receipt at the central office of the subscriber's signal on the lamp until he is connected with and is talking to the called-for subscriber. But to establish a universal service requires working over much greater distances than this.

We already have an effective long-distance service through underground cables of the Pupin type from New York to Philadelphia (90 miles) and good talking with prompt connections is an every day matter between New York and Boston (235 miles). Our long distance wires extend to Chicago and other more distant western cities, and to Washington, Baltimore, Atlanta and other places in the far south. At the present time we are extending an underground cable of the Pupin type from New York to Washington (235 miles) and are making surveys and plans for an extension from New York to Boston. More than this, by the adoption of phantom loaded overhead circuits between New York and Chicago, and by similar extensions westward as far as Omaha and thence to the Rocky Mountains, we expect by the first of January next to have so greatly extended our "Long Distance" frontier that conversation may be held between Denver, Colo., and New York City, a distance of 2,200 miles.

I have mentioned these things to give a suggestion of the intricacy and magnitude of the system for which switchboards must be provided and to bring out strongly the point of view from which we must judge the capabilities of this so-called automatic system. Our problem is national, not parochial—it is indeed even international as your presence here to-day so eloquently testifies.

We must provide for the public a comprehensive system of which switchboards form only a part; and which shall be suitable not only for to-day, and for this year and for the next, but which shall be at its best obtainable efficiency during each period of its entire life. These things we must do if we are to avoid stupendous blunders and enormous reconstruction costs.

We must regard our growing plant as the landscape architect views the subject matter with which he works. He must plant his trees and shrubs not with a view to the immediate results, but he must have in mind the space which will be occupied, and the shape and character of his plantation as it grows to maturity. He must leave room for his trees to grow and must have in his mind at the beginning the total effect which he desires to produce. So it is with us. We must not install a system because of its fancied immediate attractiveness, if we can discern, by looking into the future, that its growth must be stunted and that it can not survive the cold winters of practice. We are planning a magnificent park with its groves of trees and shrubs. We are not raising vegetables. We are planting avenues of oaks, not a bed of mushrooms.

It is with such thoughts as these that we have studied the question of different types of switchboards in America, and when thus considered, it is surprising to see how many of the features of the so-called automatic system fail to apply to the conditions of practice. Among these conditions with us is the necessity of providing private branch exchange service. This is done by locating at the subscriber's premises a switchboard provided with trunk lines extending to the central office and with a number of stations, sometimes a very large number, located in different parts of the subscriber's premises and connected with the P. B. Ex. Some of these private branch exchanges have as many as 1,200 stations connected with them. This number, however, is exceptional.

By means of this private branch exchange system a most satisfactory method of giving local connections throughout the different parts of the subscriber's premises is provided and from any of these stations by means of trunk lines to the central office, connection can be had to any other station in the entire telephone system, whether it be reached by local, suburban or long-distance trunk lines.

Notwithstanding the work that has been done and all the claims that have been made, no practical way has been discovered for doing away with the operators at these private branch exchanges, and the outlook for a practical solution meeting all of the plant, traffic and commercial requirements is so discouraging that at the present time the best opinion is that nothing but failure in this respect is to be expected. It should not be understood that at each of these P. B. Ex. switchboards, there is an operator solely devoted to handling telephone calls. While this is the case in the larger installations, in the smaller ones, of which there is a very large number, the switchboard is operated by a clerk or some one who has also other duties to perform.

This P. B. Ex. development forms one of the most satisfactory and important features of the telephone in America. Some idea of its popularity and the magnitude which it has attained and is expected to attain will be gathered from the following figures. In 1900, New York City had a total of 1,050 P. B. Ex. switchboards, located at subscribers' premises and serving 12,650 stations, connected with them. In 1910, there are 11,960 P. B. Ex. switchboards to which there are connected 162,560 stations. In 1930, as a result of our studies of this subject, we are planning for 88,400 P. B. Ex.

switchboards, having connected with them a total of 1,079,000 stations. These figures have a deep significance. They show that in the carrying out of plans upon which construction work is now being done, that we shall reach a point where more than half of the stations connected with the New York City system would require to be handled by operators, even if automatic switchboards were installed at the central office. But more operators than these would be required in an automatic system applied to New York. Large numbers of toll operators and of long distance operators and monitor operators and operators for many other classes of service would be needed.

I have not before me a computation as to the total number which would be required in the system which we are planning, but some years ago a careful study was made with a view to seeing how far the automatic system might be advantageously used in New York City at that time. It was then found that counting P. B. Ex. operators and the central office operators, the so-called Manual svstem would require 13,000 operators, and that in the so-called automatic system, leaving out of account the "Mechanician Operators," there would be required 10,000 operators.

We have studied this automatic system, not only in connection with its application to large cities, but also when applied to an entire State. For this purpose a thorough study was made of the telephone system of the State of Connecticut. This study was made by a large staff of most competent engineers and consumed several months in the making. The result of this was to show that at the time the study was made, if we counted all of the private branch and other operators needed with the Manual system, there was a total of 892 required. A similar careful study showed that if the Automatic system were installed 600 operators would be needed, not counting the "Mechanician Operators."

All these things show that the Automatic system, which has so many alluring features about it when its application to simple conditions is considered, becomes more and more unsuitable as the plant grows. Even when the automatic system is applied to the simple case of a single office district we have yet to find an instance in which the total annual charges lying against it are less than the Manual.

I am aware that statements have been made by the partisans of the automatic system purporting to show that the annual charges on that system are much lower than on the Manual. We have analysed the conditions of these cases and found the comparison was not made upon a fair basis. Where these Automatic systems have been installed, they have taken the place of obsolete or inefficient Manual systems and the comparison has been made between an Automatic switchboard of the most efficient type known and a Manual switchboard of a very defective type. In some cases the comparison has been made between the best type of automatic and the very poorest known type of Manual switchboard. It is not surprising, therefore, that from such comparisons, figures could be obtained which would appear to favour the automatic. We have been at great pains and expense to make these comparisons on a proper basis and in a thorough and fair manner.

We have made studies in a number of cities in America, taking into account the factors of operating maintenance, depreciation, taxes, insurance and so forth. In every case we found that the annual charges were in favour of the so-called Manual system.

I think enough has been said to show that the Automatic system properly considered, does not do away with operators, does not operate without the constant surveillance of skilled mechanicians, and that it is in truth not an Automatic system at all, but merely one form of Semi-Automatic system, of which the so-called Manual is another.

By such considerations as these we are led to a point from which we can approach our subject with a mind freed from bias. By so doing we clearly see that we have not to do with a partisan controversy about Manual Switch-boards versus Automatic Switchboards. We have before us a broad question in telephone engineering, requiring for its solution a clear apprehension of a host of subjects pertaining to the plant, traffic and commercial activities of the Company or Administration. It is a grave mistake to regard our problem as being one for the mechanician only. It is much broader and deeper than this, involving important questions of political economy.

Having stripped our question of its verbal disguise, we see that the two systems are not so antagonistic as would at first appear. They both stand upon this common ground: Each recognizes the importance of manual operations guided by human intelligence; each recognizes the importance of automatic machinery; each system employs both agencies; each system is semi-automatic.

We are now prepared to formulate the question anew. We see that it becomes a problem of dividing the total operations to be performed, in such a manner that labour guided by human intelligence shall be employed where it is most effective, and that automatic machinery shall be employed where it is most effective. Properly stated, therefore, our question is "What is the best type of Semi-automatic switchboard?"

The so-called Automatic system, as I have shown, is found unsuitable for the demands of a comprehensive system. The so-called Manual system has been tested by the most severe demands of a system composed of 5,000,000 telephones, and it has been found to answer every substantial requirement. By its means we are to-day giving an excellent service and our studies of the future requirements show that if nothing better is attainable, we can, with the Manual system, supply in a satisfactory manner all the demands of the public.

But it would not do for us to rest content with this. We must at all times strive for improvements. These are the traditions of the American Telephone and Telegraph Company, added to which are the specific orders from President Vail frequently reiterated, that we must constantly seek for improvements so that we may at all times when it is reasonable and practicable, place at the disposal of the public that system which solid experience has demonstrated to be the best.

Pursuant to this policy we have spent hundreds of thousands of dollars in experiments and investigations pertaining to this subject.

We have, after many years of work, developed and are now installing at New York for an experimental demonstration, a system which is avowedly semi-automatic and not disguised under another name. The advocates of this system contend that it is a mistake to place, as is done in the so-called automatic systems, complicated automatic machinery at each sub-station. (A sub-station is any telephone set at the subscriber's premises which may be connected to the central office.) They favor the use of a sub-station instrument identical with that employed in the so-called Manual, and they assert that this instrument is really much more automatic than the instrument employed in the so-called automatic system itself.

We must admit that there is much force in this statement, for an analysis of the operation of the two instruments shows that the manual operations required at the automatic station are several times more numerous than at the manual station. In fact all of the manual operations required at the manual station are also required at the automatic station. To these must be added at the automatic station a number of other manual acts, depending upon the character of the call to be sent.

It is further asserted that the apparatus at the automatic sub-station is complicated to a high degree, whereas at the Manual station it consists of simple elements, and that in consequence of this, with the vast multiplication of stations which must take place in a successful telephone system, the automatic system would be placed at a great disadvantage.

In this semi-automatic system about which I am now talking, a counterpart of the automatic apparatus which is required at each subscriber's station in the automatic system, is placed at the central office. Thus one of these pieces of apparatus is required for each "A" operator's position instead of one for each sub-station on the subscriber's premises. This greatly reduces the number of complications, and one of them being required for each operator's position only, much more money is available to be expended upon its construction. Hence it can be made with great precision and so as to give much more reliable working. Furthermore, these pieces of apparatus being at the central office, they are under the constant care of expert maintenance employees, who can instantly substitute a spare apparatus for one which should become defective.

It is contended on behalf of this semi-automatic system that the "A" operator's position (the "A" operator is the one who answers the subscriber in the first instance), is a point at which human intelligence is needed, because of the numerous exigencies of the service. I have carefully looked into this statement, and I am much impressed with the force of the reasons given in support of it. While the position of the "A" operator seems to be one where human intelligence is required, it is not so at the position of the "B" operator (the "B" operator is the one who receives the trunk call from an "A" operator at another office). When the work of this "B" operator is analysed it will be found theoretically that it can all be done by machinery and that the work to be performed does not require human intelligence. Consequently, in this semi-automatic system, all of the "B" operators are eliminated and machines substituted. This very greatly reduces the total number of operators required, and if the machinery can be made to work satisfactorily, it is believed that greater precision of working will be attained. This expectation is based upon statistics which show that a large part of the errors made at the central office take place between the "A" operator and the "B" operator.

As the pieces of automatic apparatus needed in the semi-automatic system at the "A" operators' positions in the central office are relatively small in number, it does not seriously increase the total expense to design and construct them with the greatest care and with the best workmanship, so that the utmost degree of precision may be obtained in their working. On account of the enormous number of such pieces of apparatus which would be required if they were distributed at the subscribers' premises, one for each telephone station as is required in the automatic system, the same high degree of design and workmanship cannot be applied, because the costs would be multiplied exceedingly. Hence in respect to these vital parts of the two systems, the automatic system must alway stand at a disadvantage.

The result of this has been to produce for the semi-automatic system an apparatus operated by a keyboard similar to that used on the typewriter. Working with such a keyboard, it has been experimentally demonstrated that the "A" operator can handle a very much greater number of calls than she could in the so-called Manual system. This fact greatly reduces even the number of "A" operators.

The advocates of this sytem contend that they have made the best division of labour, the best distribution of automatic machinery, and that they can attain a higher degree of efficiency and much lower annual costs than are attainable with either the so-called Manual system or the so-called Automatic system.

Engaged upon this study and upon these experiments we have had a corps of capable engineers and experimentalists working for years, and I feel warranted in attaching great weight to their favorable expectations.

Soon after my return to America, I hope to be present at the opening of the Semi-automatic switchboard, and until we have obtained the results of this working, there is not much more that I can profitably say upon the details of the subject.

In conclusion, the situation as I view it, is as follows: The so-called automatic system is not, in fact, automatic, it is only partly so. It has been fairly and exhaustively studied and found to be unsuitable for the comprehensive demands of our present service, and more and more unsuitable when considered with respect to the demands of the future.

The so-called Manual system has successfully withstood the severe demands of a system comprehending 5,000,000 telephones and all of our careful studies with respect to future growth have shown that if nothing better were obtainable, it would furnish to us a means whereby we could supply an excellent universal service to all the people of the United States.

As I have already stated, a third system, frankly called a Semi-automatic system, is about to be practically tried. If the expectations regarding it are realized, it will be a system more efficient and more economical than either the so-called Manual or the so-called Automatic.

Before leaving this subject, I wish to speak briefly upon one point. It has been said by some that we have not generally adopted the so-called Automatic system, because we have been deterred by the large expenditure of money which would be required.

I shall promptly show you that there is no truth in this. The history of the telephone in America has been that of rapid change from one system to another, as soon as improvements have been demonstrated. Pursuant to this policy, the plant at New York has been constructed and reconstructed three times. A similar story is to be told of the rest of the country. Our Company has been so conservatively financed and our Administration has been so keen to adopt new improvements, that ample depreciation funds have been accumulated so that just as soon as it is demonstrated that a better switchboard system is available, we are prepared to begin its installation and proceed with the utmost practicable speed to make the change. All of this could be done without the slightest disturbance in our financial arrangements.

While there rests upon us the responsibility of adopting as soon as it is practicable and reasonable to do so that which is best, there is a corresponding and most serious obligation of not throwing away what has been demonstrated to be a thoroughly efficient system, without having it conclusively demonstrated that there is something better. I do not see anything in the present state of affairs which need give any Company or any Administration any concern with respect to the possibilities of a sudden change, for even if it were demonstrated that a better system were now available, it would be impossible, taking into account the manufacturing and engineering resources of all the world, to make the change except in a gradual manner. We have already had so much experience with such changes that we know how they must take place. They are accomplished by a process of gradual evolution and not by sudden revolution.

In every Administration there are from time to time switchboards which have been worked for the full period of their life. These must be replaced in any event, and when such cases arise, the new type of switchboard is installed. This does not involve the abandonment of apparatus having further usefulness. There are also constantly arising cases where new installations must be made. These can be installed on the new plan. Obviously, this does not require that any existing apparatus be thrown away. The manufacturers and the Administration staffs would find themselves so fully occupied with this work that they would not for some years be able, even if it were desirable, to disturb those central offices in which the switchboards have many more years of life. It will be found that by the time the old switchboards have been replaced and the new ones installed, those switchboards which have had to be removed in advance of the expiration of their life would be few, and in those cases the work would not be anticipated by a great many years. Even where a switchboard is removed before its life has expired, this need only be done when it is found best, all things considered, to replace it by a new one rather than to continue it in service. There is nothing in this situation which demands a headlong rush, so without wasting any time, we should proceed with deliberate care.

We, who are charged with the great responsibility of rendering such an important service to the Public, cannot be justly criticised if we refuse to be carried away by the enthusiasm of Manufacturers and Inventors and thus to be led into a wholesale and probably disastrous experimentation upon the public.

In America we have pursued this subject for many years with the utmost diligence. An important practical demonstration is about to be made. We cannot foretell the answer, but we must accept it whatever it may be.

I have told some of the things we have done. It has been our constant aim to keep an open mind and to be free from bias. We are seeking only the truth and from that we have nothing to fear.

The Origin of the Industrial System[1]

Charles Buxton Going

[Scores of books and articles written by engineers deal not with physical laws and man's methods of utilizing them but with problems which seem to belong well within the provinces of the psychologist, the political economist, the business man, and the financier. To this group belongs the following general definition of industrial engineering. The series of articles of which this is one were modified, Mr. Going says in his *Preface*, to a more general audience from lectures given originally in 1908-9 under the auspices of the Department of Mechanical Engineering of Columbia University. This general definition forms part of what the author calls a "primary triangulation" of the subject. The abstract ideas with which he deals have been made clear by the concreteness with which they have been presented. Most of the comparisons and examples, it should be observed, are such as will be readily understood and appreciated by engineers.]

Industrial engineering is the formulated science of management. It directs the efficient conduct of manufacturing, construction, transportation, or even commercial enterprises—of any undertaking, indeed, in which human labor is directed to accomplishing any kind of work. It is of very recent origin. Indeed, it is only just emerging from the formative period—has only just crystallized, so to speak, from the solution in which its elements have been combining during the past one or two decades. The conditions that have brought into being this new applied science, this new branch of engineering, grew out of the rise and enormous expansion of the manufacturing system. This phenomenon of the evolution of

[1] Chapter 1 of *Principles of Industrial Engineering* (McGraw-Hill Book Company, 1911). Reprinted by permission of the publishers.

a new applied science is like those that have been witnessed in other fields of human effort when some great change, internal or external, forced them from a position of very minor importance into that of a major service to civilization. Columbus could blow across the ocean in a caravel to an unknown landfall; but before a regular packet service could be run between New York and Liverpool navigation must be made a science. It has drawn upon older, purer sciences for its fundamental data—upon astronomy, meterology and hydrography, and later upon marine steam engineering and electricity; but out of all these it has fused a distinct body of science of its own, by which new practitioners can be trained, by which certainty, safety and efficiency of performance may be substantially assured.

Navigation is not merely making correct observations of the sun and stars, of lights and beacons, of log and lead; it is not merely directing the propelling and steering machinery; it is not merely knowledge of courses and distances; it is not merely storm strategy. It is the co-ordination of all these in handling the equipment provided by the marine engineer and naval architect, through the work of a crew of men.

In somewhat like manner, industrial engineering[1] has drawn upon mechanical engineering, upon economics, sociology, psychology, philosophy, accountancy, to fuse from these older sciences a distinct body of science of its own. It does not consist merely in the financial or commercial direction, nor merely in running the power-plant or machinery, nor merely in devising processes or methods. It consists in coördinating all these things, and others, in the direction of the work of operatives, using the equipment provided by the engineer, machinery builder, and architect.

The cycle of operations which the industrial engineer directs is this: Money is converted into raw materials and labor; raw materials and labor are converted into finished product or services of some kind; finished product, or service, is converted back into money. The difference between the first money and the last money is (in a very broad sense) the gross profit of the operation. Part of this is absorbed in the intervening conversions, or, in other

[1] A systematic presentation of the field of industrial engineering from an entirely different point of view and by a very different method will be found in "Factory Organization and Administration," by Prof. Hugo Diemer; McGraw-Hill Book Co. [Author's note.]

words, in the operations of purchase, manufacture, sale, and the administration connected with each.

Now the starting level (that is, the cost of raw materials and labor) and the final level (the price obtainable for finished product) —these two levels are generally fixed by competition and market conditions, as surely and as definitely as the differences in level between intake and tail race are fixed in a water power. Hence our profit, like the energy delivered at the bus bars, varies not only with the volume passing from level to level, but with the efficiency of the conversions between these levels. In the hydro-electric power-plant, the conversion losses are hydraulic, mechanical and electrical. In any industrial enterprise the conversion losses are commercial, manufacturing, administrative. It is with the efficiency of these latter conversions that industrial engineering is concerned.

The industrial engineer may have in his organization staff many mechanical engineers superintending special departments—design or construction, or the power-plant, for instance—while his own duty is to co-ordinate all these factors, and many more, for the one great, central purpose of efficient and economical production. He is concerned not only with the direction of the great sources of power in nature, but with the direction of these forces as exerted by machinery, working upon materials, and operated by men. It is the inclusion of the economic and the human elements especially that differentiates industrial engineering from the older established branches of the profession. To put it in another way: The work of the industrial engineer not only covers technical counsel and superintendence of the technical elements of large enterprises, but extends also over the management of men and the definition and direction of policies in fields that the financial or commercial man has always considered exclusively his own.

In general, the work of the industrial engineer, or, to use a yet more inclusive term which is coming into general use, the efficiency engineer, has two phases. The first of these is analytical—we might almost call it passive to distinguish it from the second phase, which is synthetic, creative, and most emphatically active. The analytical phase of industrial or efficiency engineering deals merely with the things that already exist. It examines into facts and conditions, dissects them, analyzes them, weighs them, and shows them in a form that increases our useful working knowledge of the industry with which we have to deal. To this province of industrial engineering belong the collection and tabulation of statistics about a business, the accurate determination and analysis of costs, and the comparison of these costs with established standards so as to determine whether or not they are normal. To this sort of work Harrington Emerson applies the term "assays," speaking of labor assays, expense assays, etc., and maintaining (with good reason) that the expert efficiency engineer can make determinations of this sort as accurately, and compare them with standards as intelligently, as an assayer can separate and weigh the metal in an ore. To this province belong also such matters as systematic inquiry into the means and methods used for receiving, handling, and issuing materials, routing and transporting these materials in process of manufacture, the general arrangement of the plant, and the effect of this arrangement upon economy of operation. To this province belongs, also, the reduction of these data and other data to graphic form, by which their influence and bearing upon total result are often made surprisingly and effectively manifest. It is wonderful how much new knowledge a man may gain about even a business with which he thinks he is thoroughly familiar by plotting various sorts of data on charts where, say, the movement of materials back and forth, or the rise of costs under certain conditions, are translated immediately into visible lines instead of being put into the indirect and rather unimpressive form of long descriptions or tabular columns of figures.

The great purpose and value, indeed, of these analytical functions of industrial engineering is that they visualize the operations of the business and enable us to pick out the weak spots and the bad spots so that we can apply the right remedies and apply them where they are needed. They make us apprehend the presence and the relative importance of elements which would otherwise remain lost in the mass, undetected by our unaided senses.

The second phase of industrial engineering—the active, creative and synthetic phase,—goes on from this point and effects improvements, devises new methods and processes, introduces economies, develops new ideas. Instead of merely telling us what we have been doing or what we are doing, it makes us do the same thing more economically or shows us how to do a new thing that is better than the old. To this part of works management belongs, for example, the rearrangement of manufacturing plants, of departments, or of operations so as to simplify the process of manufacture; the correction of inefficiencies, whether of power, transmission, equipment or labor; the invention and application of new policies in management which make the ideals and purposes of the head operate more directly upon the conduct of the hands; the devising of new wage systems by which, for example, stimulus of individual reward proportioned to output makes the individual employee more productive.

The exercise of these functions, whether analytical or creative, by the industrial engineer or the efficiency engineer, requires that he shall have technical knowledge and scientific training, but in somewhat different form from the equipment of the mechanical engineer and somewhat differently exercised.

Industrial engineering deals with machinery; but not so much with its design, construction, or abstract economy, which are strictly mechanical considerations, as with selection, arrangement, installation, operation and maintenance, and the influence which each of these points or all of them together may exert upon the total cost of the product which that machinery turns out.

It deals with materials, but not so much with their mechanical and physical constants, which are strictly technical considerations, as with their proper selection, their standardization, their custody, transportation, and manipulation.

It deals very largely with methods; but the methods with which it is particularly concerned are methods of performing work; methods of securing high efficiency in the output of machinery and of men; methods of handling materials, and establishing the exact connection between each unit handled and the cost of handling; methods of keeping track of work in progress and visualizing the result so that the manager of the works may have a controlling view of everything that is going on; methods of recording times and costs so that the efficiency of the performance may be compared with known standards; methods of detecting causes of low efficiency or poor economy and applying the necessary remedies.

It deals with management—that is, with the executive and administrative direction of the whole dynamic organization, including machinery, equipment and men.

It deals with men themselves and with the influences which stimulate their ambition, enlist their coöperation and insure their most effective work.

It deals with markets, with the economic principles or laws affecting them and the mode of creating, enlarging, or controlling them.

The most important elements of industrial engineering are summed up in this alliterative list—machinery, materials, methods, management, men and markets. And these six elements are interpreted and constructed by the aid of another factor whose name also begins with m—Money. Money supplies the gage and the limit by which the other factors are all measured and adjusted. This of course is true not alone of industrial engineering; the civil engineer, the mechanical engineer, the electrical engineer, the mining engineer, each and all must normally be expected to make money for his employer or client. One of the simplest principles of the profession, but one which the mere technician sometimes finds it hardest to keep in mind, is that the primary purpose for which the engineer is usually engaged is to direct the employment of capital so that it may pay back dividends to its owners. And while this is generally true of all engineering employment, it is most particularly, continuously and everlastingly true of works management. It is much easier to conceive of the civil engineer or the mechanical engineer being retained to carry out some piece of work in which scientific accuracy is demanded regardless of cost, than it is to conceive of a shop superintendent being directed or even permitted to manufacture a line of product regardless of cost.

It is the ever-present duty of the industrial engineer, of the efficiency engineer, to study constantly, and to study constantly harder and harder, the question of equivalency between the dollars spent and the things secured. It is not sufficient, for example, for him to know that a machine sold for $100 costs $75 to make. This may be a very good profit and the machine itself may be an excellent one. There may be vouchers honestly connecting every cent of the $75 cost with some actual item of material, labor, or expense. Nevertheless, the industrial engineer must constantly look back of these figures to see whether by some change of machinery, some modification of materials, some alteration of methods, some higher skill in management, some stimulus to the men, he can make the machine cost less than $75 for its manufacture, or can make it a better machine for the same cost, or perhaps can do both.

In short, the industrial engineer is under unending and unremitting pressure to secure a true proportion between what he spends and what he gets. And the proportion is never true so long as the smallest opportunity remains for getting more in return for what he spends, or for spending less in payment for what he gets. The function of the industrial engineer is to determine with the utmost possible wisdom and insight whether and where any disproportion between expenditure and return exists, to find the amount of the disproportion, the causes of such disproportion, and to apply effective remedies.

The forces causing this pressure for the reduction of cost are principally two. The older and cruder is competition. The later and larger, which in itself carries the answer to competition, is the effort toward efficiency.

Competition was not created by the manufacturing system. It existed from the foundation of the world. But it took on a new meaning and new activity when the things began to be made first and sold after (as they are under the manufacturing system) instead of being sold first and made afterward, as they were under the older order. If you contract to buy something which is not yet in existence—a bridge, a house, a suit of clothes, or what not—the bargain is largely a matter of estimate, often, indeed, a matter of guess work, on both sides. You have to strike a mental balance between the several alternatives presented and compare in your mind net results of cost, design, quality, certainty and promptness of delivery, personality, credit, and perhaps many other things, some of them intangible, and some only to be proved by the outcome. The proposition that seems most attractive is closed; the competing ones are never carried out at all. The buyer never can tell with absolute certainty whether or not he got the best value for his money; he can only compare the thing which has been made with what he thinks the other things would have been if they had been made. The seller does not know until everything is over whether or not he made a profit, or how much. But when you sell things already made, like lathes or high-speed engines or dynamos, off the sales-room floor, the prospective buyer can make the most absolute and intimate comparison between the things and their prices. He can compare Brown & Sharpe with Lodge & Shipley, Harrisburg with the Ball engine, Westinghouse with Crocker-Wheeler. He can compare accurately design, quality, cost before a word or a dollar passes. The necessity for offering the best goods for the least money and yet making a fair profit becomes vital and insistent, and so the knowledge of actual costs and the ability to reduce costs becomes fundamental. Competition has therefore been in one way a tremendous force for economy in manufacturing. And yet, by a paradox, in another way competition has been one of the great sources of waste, by causing duplication of plant, of organization, of equipment, of sales effort, and of middlemen—none of which may have any better reason for existence than someone's desire to share in tempting-looking profits, but all of which must be paid by the consumer—all of which become a burden on society at large.

The new and ethically fine ideal, therefore, is efficiency—the reduction of costs and the elimination of waste for the primary purpose of doing the thing as well as it can be done, and the distribution of the increased profits thus secured among producer, consumer, and employee. Efficiency is a concept as much finer than competition as creation, conservation, is finer than warfare. It is a philosophy—an interpretation of the relations of things that may be applied not only to industry but to all life. Let me quote a few sentences from Harrington Emerson's "Efficiency as a Basis for Operation and Wages:"

"If we could eliminate all the wastes due to evil, all men would be good; if we could eliminate all the wastes due to ignorance, all men would have the benefit of supreme wisdom; if we could eliminate all the wastes due to laziness and misdirected efforts, all men would be reasonably and healthfully industrious. It is not impossible that through efficiency standards, with efficiency rewards and penalties, we could in the course of a few generations crowd off the sphere the inefficient and develop the efficient, thus producing a nation of men good, wise and industrious, thus giving to God what is His, to Cæsar what is his, and to the individual what is his. The attainable standard becomes very high, the attainment itself becomes very high. . . . . .

"Efficiency is to be attained not by individual striving, but solely by establishing, from all the accumulated and available wisdom of the world, staff-knowledge standards for each act—by carrying staff standards into effect through directing line organization, through rewards for individual excellence; persuading the individual to accept staff standards, to accept line direction and control, and under this double guidance to do his own uttermost best."

Efficiency, then, and in consequence industrial engineering, which is the prosecution of efficiency in manufacturing, involves much more than mere technical considerations or technical knowledge. If we consider the way in which the manufacturing system came into existence, we can quite easily and clearly discover its most important elements; we shall see particularly something that it is of the utmost importance for us to understand, and that is that it did not originate in technical advances alone, and it has never depended upon technical advances alone, but it has been influenced at least in equal and perhaps in larger proportion by economic or commercial conditions, and by another set of factors which are psychological—that is, which have to do with the thoughts and purposes and emotions of men.

The point is very important, because true and stable industrial progress, whether for the individual, the manufacturing plant or corporation, or the nation at large, depends upon a wise coördination and balance between technical, commercial, and human considerations. It is frequently necessary in addressing a commercial audience to emphasize the importance of the technical element. Before a technical audience, on the other hand, emphasis must often be laid on the commercial and psychological factors that in practical achievement must always be interwoven with the technical factor. Every great industrial organization and every great step in industrial progress to-day includes all three elements, but they will perhaps appear more distinct if we look at the origin and source of the manufacturing system, out of which this new science of industry has sprung. The origin of the manufacturing system was clearly enough the introduction of a group of inventions that came in close sequence about the end of the eighteenth century and beginning of the nineteenth. These were the steam engine, mechanical spinning and weaving machinery, the steamboat, the locomotive, and the machine-tool. It is commonly assumed that the great cause of the entire movement was Watt's improvement of the steam engine—that the industrial era which began a little more than a century ago was, so to speak, waiting in suspense, in the hush of things unborn, ready to leap into being as soon as the prime mover had been perfected to a point of practical service.

This view seems to be incomplete. The steam engine had been discovered, forgotten, and rediscovered, it would be difficult to say how often, from the time of Hero or earlier down to the time of Watt—forgotten and ignored because the world had no use for it; the economic conditions were not ripe for it. If there had been the same demand for power to pump the mines in England, the same demand for machinery in the textile industries of England, the same need for better vehicles to transport commercial products by land and by sea, in the time of Papin or the Marquis of Worcester that there was in the time of Watt, I think it is quite conceivable that the inventions which made Watt famous would have come a full century earlier, and his genius would have been exerted upon a later stage of the problem, as the genius of Willans and Corliss and Parsons and Curtis has been within the period of our own lives.

I am strongly inclined to believe that the world has always had something near the quality and quantity of engineering talent it has been able to use. When civilization was dependent chiefly upon roads, aqueducts, bridges and buildings, it got them. We have never done some of these things better, technically speaking, than the Assyrians, or the Romans, or the architects of the great cathedrals of the Middle Ages; some, indeed, we perhaps never shall do again as well. Newcomen, Watt, Arkwright, Stephenson, Bessemer, applied genius to a new sort of opportunity, rather than embodied in themselves a new order of genius. They may indeed have been greater than other workers who preceded them, but the more important element in their success is that the world was at last ready and waiting as it never had been before for the peculiar product of genius they had to offer. This readiness that opened the door to their success was due to economic or commercial conditions, not merely to the technical invention. In its larger relations, then, technical success depends upon commercial opportunity. There must be a potential market. Bessemer steel could not have found any welcome in the Stone Age. The typewriter would not have succeeded in the Dark Ages when no one but a few clerics could read and write. Savages who traded cocoanuts for beads and brass wire could afford no encouragement to the manufacturer of the cash register or the adding machine. It was not because of thermodynamic inefficiency that Hero's engine failed of adoption. On the other hand, when the world was ready for steam power it accepted very gladly to begin with a very crude machine, and technical improvement went step by step with larger practical utilization, sometimes leading and sometimes following. There must, then, be a potential market or application, or advance in the applied sciences will be limited. This is an axiom to be placed alongside of another—that there must be scientific study and research, or industries based upon the applications of science will stagnate and remain at a low stage of efficiency.

The second factor in industrial progress, then, is the commercial factor. There must be a potential market; but it does not follow from this that technical progress is wholly subordinate to economic conditions. The inventor or the engineer is not of necessity merely a follower of progress in commerce or industry. Many of the great advances in applied science, or in branches of industrial achievement perhaps too lowly to be called applied science, have been made by man, who foresaw not only technical possibilities but commercial possibilities—who undertook not only to perfect the invention but to show the world the advantage of using it. I think this was substantially the case with wireless telegraphy, with the cash register and typewriter. Nobody had demanded these things because nobody had thought of them, and the productive act in each instance included not only technical insight into the possibilities of doing the thing, but human insight into the fact that people would appreciate these things and use them if they could be furnished at or below a certain cost. Modern industrial methods have shown us that in many cases there is no such thing as a fixed demand beyond which supply can not be absorbed, but that demand is a function of cost of production. There may be no demand at all for an article costing a dollar, but an almost unlimited demand for the same article if it can be sold at five cents. A large part of the work of the production engineer lies in the creation of methods by which the cost of production is decreased and the volume of production is thereby increased, with advantages to both the producer and the consumer.

In all these cases you see that technical achievement, technical success, is closely interlocked with industrial or economic conditions, and with the understanding and control of industrial or economic influences and forces.

The third factor in industrial progress is the psychological factor—the element contributed by the mental attitude, emotions, or passions of men. I might suggest its possible importance by reminding you that there were centuries in which the inventor of the steam engine, far from being rewarded, would have been burned at the stake as a magician. This would not have been because the extraordinary character of the achievement was unrecognized, but because its nature was misinterpreted. That particular form of expressing intellectual dissent has gone out of date. We are much more civilized now, and nineteenth- or twentieth-century inventors who are far ahead of their times are no longer burned; they are merely allowed to starve to death; while those who are timely, but not commercially shrewd, are usually swindled by some promoter, who in turn is frozen out by a trust. In any case, you see, the simple technician gets the worst of it industrially, not because his physical science is weak, but because his commercial and mental shrewdness is not correspondingly developed.

Taking a larger view of it, we shall see that almost every important advance in engineering progress is made only after a period of pause, an interval following proof of the technical achievement, following even demonstration of its commercial economy. We might call this the psychological lag—the time necessary for the growth of human faith sufficient to energize an industrial movement. In the case of the electric railway, or the motor vehicle, for example, this lag was measured by years. Bessemer could not convince the ironmasters of England, and had to build his own plant. Westinghouse, having gained after much difficulty an audience with the greatest railroad manager of that day, was told that this practical railroad man had no time to waste on a damn fool who expected to stop railroad trains with wind. The matter deserves emphasis because it is almost certain to enter into the individual experience of every man. You will have to make someone believe you, and believe in you, before you can get anywhere or do anything. When a technical man has a proposition to put before an individual, or a group of individuals, or society at large, he is very likely to think that scientific demonstration of its technical soundness ought to be convincing. You will find, however, that men at large will substantially ignore scientific proof, and that you must add to it, second, proof of the commercial or economic argument, and third, that psychological force which convinces not the reason, but the emotions. In all industrial engineering, which involves dealing with men, this psychological or human element is of immense, even controlling importance. The principles of the science are absolute, scientific, eternal. But methods, when we are dealing with men, must recognize the personal equation (which is psychologic) or failure will follow. The differences between the several philosophies of works management as expressed in the wage systems which we are going to consider later are psychological. Success in handling men and women, which is one of the most important parts of the work of the industrial engineer, is founded on knowledge of human nature, which is psychology.

The great industrial movement, then, with which we have to do is triune in its nature, the three chief elements being the technical or scientific, the economic or commercial, and the psychological or human. They seldom respond at equal rates to the impetus of advance. Sometimes the technician pushes so far ahead that the world loses touch with what he is doing and his work lies long unused until civilization catches up; sometimes the commercial tendency is unduly aggressive, and discourages or impedes real scientific achievement; very often the men most concerned with the industrial activities go badly wrong in their philosophy, and get disastrously false notions as to what makes for real progress and real welfare. More difficulties, perhaps, come from this cause than from any other.

To the technical man, it is an ever-present duty to keep in view absolute ideals, to seek every chance for their advancement, and to mould conditions and men so as to obtain constantly nearer approach to these ideals; but in doing this he must never forget to attach full weight to economic conditions, and he must never allow himself to ignore human nature.

CHAPTER IX

REPORTS

INTRODUCTION

Engineering reports do not really constitute a separate and individual type of technical writing; they consist rather of a fusion of the types already considered, and gain their distinctiveness from their aim and the circumstances under which they are written rather than from the elements which compose them. They are, if one may borrow a name from a type of poetry, technical articles *of occasion*, written to order for a specified reader or group of readers and having as their aim the supplying of a definite body of information on a specific subject, with or without recommendations based on the data collected. Their types are so various as almost to defy classification; some of the more usual types follow:

1. *Information reports*, which consist entirely or almost entirely of a body of selected data gathered by an experienced observer.

2. *Recommendation reports*, in which the important elements are conclusions or recommendations based upon collected data which may or may not also be presented. To this class belong the reports, for example, made by an expert municipal or sanitary engineer to a city council.

3. *Progress reports* made, usually at regular intervals, upon a piece of engineering construction under way.

4. *Research reports* based upon definite research work.

To this type belong, for illustration, most of the reports written by government experts for publication in government bulletins.

Student reports differ from professional reports as a broomstick gun differs from a rifle. Their function is to instruct the student in the facts of engineering science and to train him to observe intelligently, think rationally, and record his observations and conclusions accurately and clearly. The reader of the student report, who is usually also the overseer of the experiment or investigation reported, is not dependent, as is the reader of a professional report, upon the data and the conclusions presented by the student; he is, in effect, the servant of the reporter, paid to assist in his training, and not, as in the case of a professional report, a superior who has delegated a definite task to him. But the mental and moral elements which enter into the task of student report writing are, nevertheless, the same as those which figure in the most complicated report of the professional engineer; and the student, therefore, who refuses to enter seriously into this part of his work is deliberately lessening his chances of later success. Most of the principles of report writing which follow apply, then, alike to student and professional reports.

Fundamental Qualities

Engineering reports, as has been said, contain, or are likely to contain, elements of technical description, process-exposition, and exposition of ideas. Any report, therefore, may demand from the writer an application of the principles of these forms of technical exposition. Since these principles have already been explained in earlier chapters, they need not, however, be taken up here. In addition, engineering reports make upon the writer certain demands which arise more or less directly from their peculiar nature and purpose; and these will be discussed briefly. Most of these qualities pertain rather to the writer of the report than to the report itself, and may seem, for that reason, hardly to belong to the compositional side of report making; but as their presence results in good reports and their absence in bad ones, their consideration is really justified. What follows is merely an attempt to analyze and crystallize common sense in report writing.

1. *Analysis of the Problem.*—Engineering reports have been defined (page 348) as "technical articles . . . written to order for a specified reader or group of readers and having as their aim the supplying of a definite body of information on a specific subject." It will be seen, then, that the first task of the report writer is to make certain that he understands his problem. When a committee appointed to make an investigation holds its initial meeting, the first step taken is usually the definite determination of the things to be investigated and reported upon. In the finished report the specific limits of the field of investigation as the committee understands them are usually indicated clearly in the opening paragraphs. Similarly, an individual has the task in all but routine reports of determining what the limits of his field are, just what special facts he is to investigate and report upon, and whether he is expected merely to present data or, in addition, to make recommendations. Such a clear introductory analysis of his problem will insure his confining his attention to the details wanted by the readers of the report and will prevent him from wandering into

fields beyond the limits of his special investigation. An analysis of his problem need not keep him from presenting, on the other hand, data which will really be useful to the reader of the report.

2. *Promptness.*—The student who is refused credit for a late report sometimes thinks that his instructor is hard-hearted. He does not stop to consider that out in the world big economic leaks often result from the failure of employees to furnish information *at the time when it is needed.* In college when a report is not submitted on time, the student alone is the loser; and he is merely warned or penalized by his instructor. In practice when a report is not submitted on time, the work of others may be seriously interfered with, and the dilatory report writer is at once branded as unreliable. In practice social engagements, pressure of work, sickness even, must not interfere with the task of getting the data in on time. The following little dialogue between a superintendent and a young engineer is typical.

Superintendent: "Mr. Jackson, can you get this information for us by noon of next Tuesday?"

Mr. Jackson: "I'll do my best, sir."

Superintendent: "No; your *best* will not do. The directors must have those data by noon on next Tuesday. If you can't get the information, I'll ask Mr. Ray to do so. Can you do it?"

Mr. Jackson: "Yes sir."

And Mr. Jackson, being wise, gets the report in on time.

3. *Accuracy.*—The training in accuracy of observing and recording which it is the aim of student reports to provide is in practice one of the most necessary of moral qualities. Incorrect data are worse than useless, for con-

clusions and actions based upon them are, necessarily, also incorrect. A young engineer who through carelessness or incompetency constantly submits incorrect information is an economic loss to his employers, and his chances of ever obtaining any position of responsibility are, therefore, *nil*.

4. *Honesty*.—The writer of a report should never forget that he is not the master but the servant of the facts which he is gathering. No sound conclusions can possibly be based upon facts which have been controlled or juggled, and, moral considerations quite aside, it is entirely unscientific to fail to record data exactly as they are found. The temptation which often comes to the student in the laboratory to warp the data slightly away from the truth in order that a known conclusion may be more easily reached has its counterpart in the world in the temptation which comes to a paid investigator to bend facts to a desired conclusion or to manufacture evidence so that he may secure results pleasing to his employers. In college the offense seems slight and individual, and results too often in only a light penalty. In practice it is often criminal, since it plays fast and loose with the well-being of society, and the penalties are correspondingly severe.

5. *Completeness*.—The writer's analysis of the problem should not lead him to omit elements needed in the report. He should be careful to cover all points and to include all data likely to be of use to the reader. Failure to do this may result in the necessity for supplementary reports and in consequent delay and economic loss.

6. *Brevity*.—As far as is consistent with completeness of information engineering reports should be as brief as possible. Busy men have little time for anything but

the core of the matter; they cannot usually wade through elaborate and unnecessary explanations. The first report of a conscientious young engineer, now well advanced in his profession, was six typewritten pages in length and was plentifully decorated with drawings and stuffed with intricate mathematical proofs. "Uh-huh," said the superintendent, as he held one hand over his mouth and rapidly turned the pages with the other; "very good, very good. Now would you mind cutting it down and giving me the gist of it in a page or two?" That was ten years ago. The other day the same young engineer made the following verbal report to his chief:

Superintendent: "Did y' inspect that machine?"

Engineer: "Yes, sir."

Superintendent: "Any good for our purposes?"

Engineer: "Yes, sir; we ought to have one."

Superintendent: "All right."

Here are the elements of a complete report. And, it might be added, there are probably more reports of this latter type than of the former.

7. *Neatness.*—Lack of neatness in reports usually goes hand in hand with inaccuracy. Indeed, a slovenly report serves to draw immediate suspicion upon the correctness of the data and the soundness of the conclusions, for it is logical to infer that the report writer who is careless in the form of his report will also be careless in the substance. Since, moreover, a slovenly report is irritating and more difficult to read than a neat one, it follows that the reader is prevented from giving his complete attention to the content. Carelessness in the form of the report may, furthermore, be a positive bar to a clear understanding of the ideas, since slovenliness usually means illegibility of letters and figures and inaccuracy of dia-

grams. Although there is, perhaps, the possibility of wasting time in excessive neatness, the habit of making reports attractive in appearance, while not as important as some of the other qualities mentioned, is nevertheless much to be desired.

8. *Clearness.*—No matter how good the data may be, how sound the conclusions, or how neat the appearance, a report will be useless if it cannot be understood. "Look at that report," said a factory superintendent recently to his English instructor brother who was visiting him; "I can't make head or tail of it, and yet that man is a college graduate. He is only a foreman and will never be anything else because he can't make himself understood." On examining the report the instructor found it full of errors in sentence construction. The factory superintendent did not know the names for these faults; he knew merely that he could not understand the report, and that was enough.[1] It behooves the writer of a report, therefore, to make reasonably certain that the sentences of which the report is made up are understandable; in practice this means the avoidance of such errors as are explained and illustrated in Chapter V.

9. *Logical Errors.*—Some general comments on the very important matter of logical reasoning have already been made in the chapter on exposition of ideas (see pages 260–261). All of these apply in report writing. Without meaning in the least to be inaccurate or dishonest, inexperienced writers of reports are prone to distort facts by making impossible statements and sweeping generalizations. All statements which are manifestly

[1] This illustration and all others used in this chapter with one exception (that on p. 351) were not invented by the author but were taken from his personal experience or that of his colleagues; the exception is, I am told, a stock story frequently used by engineers.

untrue or absurd and all propositions based on very slight data should be carefully avoided. The *post hoc, propter hoc* fallacy is of frequent occurrence in report writing; this is the bad logic which leads the writer to assert that a phenomenon *results from* another phenomenon merely because it chances to coincide with it, whereas in fact the relationship between the two may be merely accidental. Another frequent logical flaw results from the writer's failure to indicate the limits of error in his conclusions, and to point out the variations possible under varying interpretations of the submitted data. All of these weaknesses detract from the force and value of a report even where they do not result in actual misunderstanding, and they should, therefore, be carefully avoided.

Organization of the Report

A great many engineering reports consist simply of data filled forms, and such reports naturally present to the writer only the problem of collecting the data and filling in the blanks. In these forms the arrangement of details is carefully planned, usually by those who are to read the reports, on the basis of information desired, convenience in arrangement, and other considerations. Many times, however, the organization of the report is left with the writer, and his problem may in all such cases be as complex as though he were writing an exposition of ideas. It need hardly be said that a clear and logical arrangement of the parts is as necessary in a report as in any other technical exposition. In the matter of plan each report presents, to a certain extent, its own difficulties, and must, therefore, be studied independently. It will be possible here, accordingly, merely to record some general principles of organization which have been found useful. Some further suggestions for the organization of student reports will be given in a later division of the chapter (see pages 358–365).

One of the simplest forms of report is that in which the arrangement of parts is chronological. The arrangement of parts of an inspection report may, for example, simply correspond with the order in which the various details of the inspection were undertaken, with, of course, proper emphasis upon details of greatest importance. In such a report the writer need only exercise care in marking his divisions clearly.

Where, however, the divisions of the report must be logically and not merely chronologically arranged, the problem is more difficult. In such cases the writer must determine the order of topics after a careful consideration of such matters as interdependence of parts, comparative understandability of details, and emphasis. At times the relative position of two details is at once apparent; it is obvious, for example, that a report on a power plant would normally consider the generating elements before taking up the transmission system. At other times, however, the relative position of parts is by no means so easy to determine; the entire question may, in fact, be exceedingly complex, as is indicated by the specimen report outlines on pages 379–387. In all such cases it becomes the duty of the writer to plan his report according to his best judgment based on an analysis of his material and of the particular needs of his reader.

The necessity of keeping in mind the point of view of the reader is coming more and more to affect the form of reports, and has resulted, especially in long and complex reports, in various devices for saving the reader's time.

For example, the practice is increasing of putting at the beginning of the report a brief abstract or summary of the principal items taken up in the body. To this is often added an analytical table of contents, with page references. These devices serve the same purpose that head-lines and introductory paragraphs do in a newspaper; they enable the busy reader to see the content at a glance. Frequently, too, where the results of the investigation and not the data are of first importance, the conclusions are put at the beginning of the report, detached from the body, so that the reader can turn to them at once. Where they occupy their normal position at the end, each conclusion is for purposes of distinction paragraphed separately. When the report is designed to be read by lay readers it is, moreover, frequent practice to relegate to an appendix all highly technical discussions, calculations, and derivations of formulas. Ease in reading the report is frequently increased by the use of sub-titles to mark new divisions, and by various other visual devices. All of these tricks assist the busy reader to secure at once a general idea of the scope and conclusions of the report and to turn immediately to any division which may especially interest him.

Student Reports

The difference between student reports and professional reports has already been indicated (page 349). The student report is essentially a piece of drill work. The reader of the report cares nothing for it as a body of collected information or an expression of expert judgment; he cares everything for it as an indication of the student's ability. The student report writer should aim, therefore, to convince his instructor that he can observe intelligently, think rationally, and record accurately and clearly. Observing intelligently means observing with the head and not merely with the eyes; it means selecting unerringly from a mass of details those which are significant and worth noting; it means that the observer's brain should be a synthesizing and not merely a recording organ, and should be constantly at work relating the details observed with one another and with principles and laws which they illustrate. Thinking rationally means using intelligently the details observed; it means coördinating details, inducing conclusions, testing results, and avoiding logical errors,—making the mind, in brief, master of the information gathered. Recording accurately and clearly means, finally, setting down data and conclusions with care that the written record be an exact report of the work of the brain and that the ideas set forth be immediately clear to the reader. These general principles of report writing apply to all types of student reports. There still remain a few special considerations in connection with the laboratory report, the inspection trip report, and the thesis.

Laboratory Reports.—A student laboratory report is a record of a test or experiment conducted by a student either alone or in coöperation with others. Laboratory experiments and tests aim to do more than give the student manual skill in handling the apparatus; they aim to teach him principles and general methods and to increase his capacity for thinking rapidly and clearly. The report based upon them should, therefore, be more than a mere mechanical and perfunctory record of things seen and done; it should reveal an understanding of the principles involved.

The form of the laboratory report is usually prescribed by the instructor or by the laboratory manual. It varies, of course, with the nature of the experimental work and with the equipment available. The following elements, however, usually appear in the order named:

1. *Introduction*, which includes a statement of the object of the experiment and, frequently, of the chemical, mechanical, or other principles involved.

2. *Description of the apparatus*, with whatever sketches are necessary; in experiments in the electrical laboratory this is frequently supplemented by a diagram of connections.

3. *Method of conducting the experiment or test.*

4. *Conclusions and comments.*

5. Where necessary, *data sheets, curves, and other records* of the experiment.

All divisions of the report should be distinctly labeled and paragraphed separately.

Inspection Trip Reports.—An inspection trip aims to give the student an acquaintance with scientific laws and principles in application. In the details of a factory, railroad station, or hydro-electric plant he meets the embodiment of the scientific knowledge which he has acquired in lecture hall and laboratory. It follows, therefore, that the most important element in an inspection trip is intelligent observation; the student should observe details not as meaningless details but as illustrations of scientific principles in operation; and he should learn to select for his inspection trip report those things which are significant. A mere empty catalogue or inventory of things seen is usually a pretty clear indication that the student has not yet learned to observe with the eye of an engineer.

The form of the report must naturally be determined anew for each trip. One of the best methods of organization is that based on a thoughtful analysis of what is significant and worth reporting and an arrangement of these details by topics. A mere loose, running narrative is likely to be perfunctory and careless, although it need not be if the writer selects the details of his report carefully and remembers that he is writing not a story but an exposition.

The following directions for preparing inspection trip reports may be taken as typical of those frequently issued to engineering students. Due emphasis has here been put, it will be noted, upon an intelligent selection of significant details in gathering the data and upon a correct and clear use of English in preparing the written report.[1]

Civil Engineering Inspection Trips—University of Wisconsin

Instructions for Preparing Trip Reports

April 1 1916

Make-up.—1. Reports may be hand-written in ink or typewritten.

2. Paper shall be of letter size (8½ in. by 11 in.), white, and of good quality.

3. A Manila cover shall be provided to which the pages shall be fastened in a way that will permit of easy inspection.

4. A letter of transmittal, addressed to "The Civil Engineering Trip Committee," shall accompany the report. Such comments or suggestions as it is desired to make shall be included in this letter.

5. The pages shall be numbered and an index provided.

[1] These directions were prepared by a committee of civil engineering instructors and are here reprinted by generous permission of Professor L. Van Hagan of the University of Wisconsin.

Length.—Instructions as to the minimum number of words that will be accepted will be issued for each trip. There is no maximum limit; the report may be as complete as desired.

Method of Treatment.—The report shall be more than a mere catalogue of places visited and things seen. It should show an understanding of the broader scientific and economic features of the works inspected.

The following is an example of a style of report writing that is quite common and wholly unsatisfactory:

"On the first floor are found the ticket offices, an information window, a lunch room, a drug store, a parcel room and a baggage-check room. On the second floor are found a dining room, a periodical booth, and toilet rooms. In the basement are found an air-washing plant, pumps, and a lost-baggage room."

As it stands, the paragraph is of no particular interest to the reader and indicates no more valuable quality in the writer than an ability to see and record the obvious. Any person who can read and write can produce a report of that character. It shows no great mental development nor any great breadth of view. But if, instead of cataloguing the things he saw, the writer had given a discussion of why the ticket offices are located on the first floor instead of on the second, or an explanation of the need for washed air and a description of the operation of the air-washing plant, his report would have considerable interest to the reader and would indicate that the writer had grasped something of the purpose underlying the inspection.

When a certain piece of machinery or other equipment possesses individual interest because of its unusual size, construction operation, or field of service, it may be mentioned; but as a rule there is no reason to list the engines, machines, boilers, etc., that are usually more or less the same in all plants.

The following outlines will indicate in a general way what is meant by "the broader scientific and economic features of the works inspected."

I. *Manufacturing Plants.*

1. *Purpose of the Plant:*

The product of the plant.

Industrial importance of the product.

2. *Location of the Plant:*
   Effect upon choice of location of—
      Cost of land,
      Transportation facilities,
      Material supply,
      Fuel supply,
      Labor supply.
3. *General Arrangement of the Plant:*
   Facilities for receiving raw materials.
   Movement of product through shops during manufacture.
   Shipping facilities.
   Source of power.
4. Special Features that Distinguish the Particular Plant from Others of its Class:
   Interesting details of manufacture, etc.

II. *Bridges, Buildings, Foundations, and Pavements.*

1. *Type:*
   Type used.
   Room for its use under existing conditions.
2. *Methods of Erection or Installation:*
   Difficulties, usual and unusual.
   Contractor's equipment.
   Arrangement of contractor's plant.
   Detail methods.
3. *Special Features:*
   Interesting details.
   Condition of pavements.
   Methods of operation of bridges.
   Maintenance.

Spelling.—The spelling shall be correct.

English.—The language shall be as concise, clear, and grammatical as the ability of the writer will permit. It shall be chosen with care and precision; loose, sweeping, inaccurate statements shall be avoided. The writer shall aim to avoid, on the one hand, amateurish expressions, and, on the other, stilted phrasing. A report consisting of incomplete and disconnected sentences carelessly thrown together will not be accepted.

It is not to be expected that a student will be able to produce an acceptable piece of work without devoting some thought and care to its preparation. The system of sitting down and, without previous thought, writing until a certain number of words have been put together, and submitting the product without further correction usually results in an unacceptable report. It is recommended that an outline be prepared before the actual writing is commenced. This outline should include the various items that are to be covered in the report. The preparation of such an outline will necessitate a consideration by the student of the relative values of the various items, will enable him to select the more important, and will aid him to obtain a better proportioned report.

The following miscellaneous suggestions point out some of the more common weaknesses of reports that have been submitted in previous years:

1. *Avoid ending a sentence weakly.*

   Examples: "Cranes weighing one hundred and fifty tons are now being built."

   "An inspection of the plant was made."

   Comment: Put the "punch" at the end of the sentence, where it is most effective. The sentences should read: "Cranes are now being built that weigh as much as one hundred and fifty tons." "An inspection was made of this plant."

2. *Avoid loose, sweeping, and inaccurate statements.*

   Examples: "As we passed through the shops, we saw engines of *every* type from the *smallest* switch engine to the *largest* mallet type, including all types that have been developed of late years, Atlantic, Pacific, and Mikado included."

   Comment: No such wonderful collection of locomotives was actually seen.

3. *Avoid statements that are obviously incorrect.*

   Examples: Speaking of a placer dredge,—"It is very massive in construction, weighing more than a million tons."

   In the boiler shops there was "an accumulator for 1500 lb. pressure" for supplying air to the riveting machine.

   Comment: Both statements are so far from actual facts that the inaccuracy should be apparent to any third year student in Civil Engineering.

4. *Avoid the split infinitive.*

   Example: "If he works on one plan for a time, then changes to another, only *to again and again change* . . . ."

Comment: The infinitive is "to change." The sentence should read, ". . . . only to change again and again."

5. *Avoid loose use of "they" and "their."*

Example: "New engines, cars, and their parts are built and assembled in the shops. *They* cast their own wheels and forge all their own driving wheels."

Comment: No antecedent is given for "they." It is used in a loose, conversational way that has no place in careful writing.

Theses.—Engineering theses are virtually long reports based upon experiments, tests, and other investigations. Their aim is to give the student training in creating or assisting to establish a proposition by evidence more extensive and complex than that involved in the simpler laboratory tests and experiments. Engineering theses are not different in nature from the reports of investigations conducted by experts in government and private laboratories, and for this reason some of the best models for theses may be found in the various government bulletins and technical papers, which are readily accessible.

Where the field of investigation is not artificially restricted, the first step to be taken in thesis writing is usually a careful analysis of the problem and limitation of the field of investigation. This is necessary that the writer may not undertake a problem which cannot be handled adequately with the equipment at his disposal.

The next step in a great many theses is the determination of the extent and results of investigations already completed in the same field. This will ordinarily mean a diligent search for written records of these investigations; they may be found in books but are more likely to be found in that immense and never finished encyclopædia of scientific information, the technical journals. Theses of former students, since they are not likely to be the work of finished experts, should be used with caution. Indeed, all second-hand information, as has already been said in the preceding chapter, should be employed with due regard for its reliability. In the finished report due credit should be given, usually in a foot-note, for all second-hand material, and if the obligations have been at all extensive, it is well also to include in an appendix a bibliography of books and articles referred to.

Subsequent stages in the collection of data and the composition of the thesis will be determined by the nature of the investigation and cannot, therefore, even be suggested here. An examination of the organization of material in government reports of investigations may prove helpful but should not be allowed to result in an attempt at exact reproduction of form, which is certain to end unsatisfactorily.

A final word about thesis writing: excepting where the thesis subject is automatically narrow and specialized,—such, for example, as comparative tests of two gas engines,—the thesis is likely to be perfunctory unless it reflects a genuine and vital interest on the part of the writer. He should be willing to live with his subject and scrutinize everything with regard to its possible connection with his thesis. If, for example, he is a civil engineering student investigating the comparative values of two kinds of pavement, a chance item on the subject in his technical journal, a chance remark of a friend or of a road-mender, a suspicious bulge or crack in a pavement which he happens to be observing should alike be regarded as possible material. And it is only by being thus perpetually alive to his investigation that he can create a report which will be solid and vital.

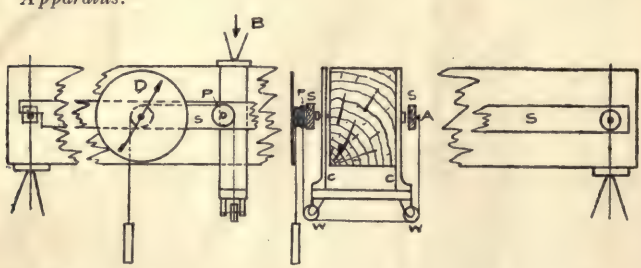
STUDENT REPORTS[1]

[Because of the variety of forms no attempt has been made here to reproduce a representative selection of student reports. The following are *not designed to serve as models but merely to provide material for class analysis*; they should be supplemented by student reports brought to class from the laboratories. In editing, the data sheets and graphs of the original reports have been omitted].

1. Cross-bending Test of a Wooden Beam

Object.—The object of this test is to study the action of and the internal stresses in a wooden beam subjected to cross-bending loads.

Apparatus.—



The apparatus for this test consisted of a Johnson testing machine, scale, knife-edges, deflectometer, clamp, and Oregon fir beam. The beam was placed on knife-edges below the Johnson testing machine so that the load would be applied half way between the supports. One of these supports or knife-edges rested on a scale which measured half the applied load. In the middle of the beam directly under the load was attached a dial wound deflectometer. The sketch above explains the principle on which this instrument works. Two strips of wood, *S*, one on each side of the beam, were supported on pins placed on the neutral

[1] For the hydraulic laboratory reports the editor is indebted to Professor C. I. Corp of the College of Engineering, University of Wisconsin.

axis of the beam directly over the end supports. On these strips pulley P and the dial and drum D were attached. The dial was graduated to thousandth parts of an inch. Clamps, C, were fastened with screws to the side of the beam under the load, and pulleys, W, were fastened to the lower part of these clamps. From the point A on strips S a number 36 copper wire passed over the pulleys, W, and P, to the drum on the recording dial. The arrangement of the deflectometer apparatus was such that the strips, S, remained stationary as the beam was deflected. It is obvious that a double value of deflections will be recorded on the dial since the vertical wires leaving pulleys W measure the deflections on each side of the beam.

Method.—The load was applied gradually at B (see sketch) in increments of about 400 lbs. The first crack in the beam occurred under a load of 4100 lbs., and failure resulted from a load of 4500 lbs., although a load of 5450 lbs. was applied before the beam was totally ruptured.

Conclusions.—The facts to be noted of this test are that the moduli of rupture and of elasticity of Oregon fir are about $\frac{1}{6}$ and $\frac{1}{14}$ respectively of those of mild steel, and that the energy of rupture per cubic inch is very much less than the energy of rupture in tension. This latter fact can be attributed to the decrease of stresses from the outer fibers to the neutral axis of the beam and from the load to the supports in a beam under cross-bending loads, whereas a specimen under tension or compression loads has every particle subjected to equal stresses.

2. Fluid Differential Gages

Object.—The object of this experiment is to study the principle of the differential gage and to determine the gage coefficient.

Apparatus.—

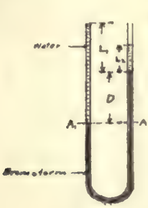


FIG. 1.

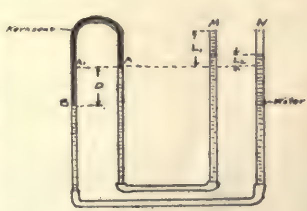


FIG. 2.

The above are diagrammatic sketches illustrating the apparatus used in this experiment. Fig. 1 shows that used with fluids heavier than water, and Fig. 2 that used with fluids lighter than water. The two fluids were respectively bromoform and kerosene. The difference in heads is obtained by varying the water levels in the tubes and thus producing different pressures. Vernier scales are provided on all tubes so that the scales may be read more accurately.

As water is poured into M, the pressure at A increases, forcing the kerosene up at A and down at B. As the height of the water column is increased in N, the kerosene is forced in the opposite direction.

Let N = the specific gravity of water, and S = the specific gravity of the fluid.

Then since the pressures at the same levels A and A_1 in the closed tube are the same for equilibrium, we may equate these pressures, obtaining:

$$NL_1 + DN - DN = NL_2 + DN - DS$$
$$N(L_1 - L_2) = D(N - S).$$

But $N(L_1 - L_2)$ is the difference in pressure or head; $\therefore$ let $h = N(L_1 - L_2)$.

Then $$h = D(N - S) \text{ or } \frac{h}{N} = (N - S)$$

$N - S$ is a constant. Let $N - S = C$.

Then $$\frac{h}{D} = C,$$

the gage coefficient.

In the case of the fluid bromoform, heavier than water, we obtain by equating the pressure equations at the level A_1, A:

$$NL_1 + hD = NL_2 + DS$$
$$N(L_1 - L_2) = D(S - N).$$

Denoting $N(L_1 - L_2)$ by h, as explained above,

$$h = D(S - N)$$

where S is greater than N since in this case the bromoform is heavier than water;

$$\therefore \frac{h}{D} = (S - N) = C,$$

the gage coefficient.

As shown on the following data sheet, the deflection in the levels of the kerosene, the lighter fluid, was much greater than that in the case of the bromoform, which made D much larger in the former case. Hence, since the coefficient $C = \frac{h}{D}$, this would be greater in the case of the heavier fluid as shown in the data.

The reason why it is not desirable to take the readings of difference of head less than 0.2 ft. is that a very small error in reading would cause a relatively large error in the gage coefficient. Moreover, when the liquid rises or falls only a small amount, there is a greater tendency for the fluid to cling to the sides because of capillary attraction, which produces an error in the result.

Besides capillary attraction and its effects other causes for error which might take place are irregularity in the inner surface of the tube, or the presence of dirt and dust. Moreover, the scale readings were not placed on the glass according to calibrations but were on a separate background, and if the diameter of the tube were smaller than it should be so that the fluid would rise higher in the tube than it should normally, the circumstance of the scale's not being calibrated on the glass by test would result in no detection of the error but the recording of a higher reading.

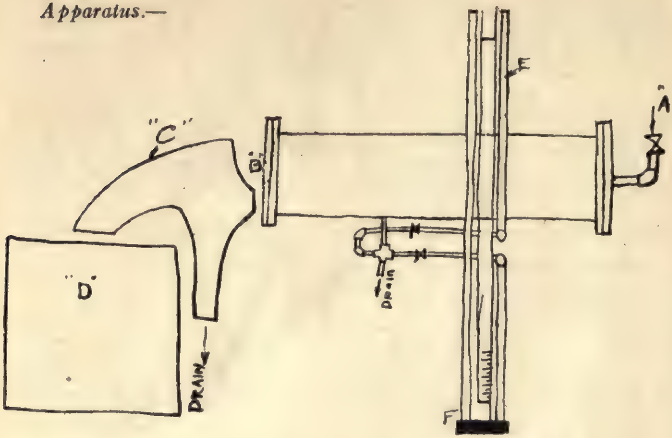
It is not desirable to compute gage coefficients from the density of the fluids because the density varies with the temperature, and because the density of the same fluid varies Moreover, we are determining the gage coefficient with a definite apparatus, and the gage coefficient is changed because of the errors mentioned above,—variation of the size of the tube, clinging of the fluid to the tube, etc.—all of which would affect the coefficient of this gage but would not have been taken into consideration had we used method of density.

[Two data sheets have been omitted in editing.]

3. The Orifice

Object.—To study the effect of change in head on the coefficient of discharge and to determine the coefficient of discharge for an orifice.

Apparatus.—



A sketch of the apparatus used in this experiment is shown above. The water enters the receiver at *A* under pressure, and flows out of the orifice *B* into one of two openings in the conveyor *C*. One of the openings, the upper, conveys the water to the measuring tank *D*, which sits on a Fairbanks-Morse scales. The other entrance to the conveyor leads to a passage which carries the water to the sewer. A lever is provided by which the conveyor can be quickly raised or lowered, thus transferring the flow from the sewer to the tank or vice versa.

The pressure in the receiver can be regulated by the valve at *A*, thus giving any desired head on the orifice. The pressure head is measured by the piezometer *E* for low heads and by the mercury gage *F* for high heads.

Method.—The zero gage reading was determined by making the water level with the bottom of the orifice. The reading of the gage plus half the diameter of the orifice gave the zero reading.

Runs were then taken with different heads on the orifice, the heads being adjusted by means of the inlet valve. Readings of the gage were taken every minute. The discharge was measured by means of the scales.

Formula.—The quantity of discharge in cu. ft. per sec. = $CF\sqrt{2gh}$.

Considering velocity of approach, the formula becomes $q = CF\sqrt{2g\left(h + \frac{V_1}{2g}\right)^2}$, where V_1 is the velocity of approach.

Sample computations; Run No. 1:

Rate of discharge in cu. ft. per sec. $= \frac{500 \times 62.5}{62.5 \times 405} = .01975$

Mean velocity of approach $= \frac{.01975}{.6^2 \times .7854} = .07$ ft. per sec.

Actual head $= \frac{V_1^2}{2g} + h = \left(\frac{.07}{2g}\right)^2 + 1.057 = 1.057.$

Theoretical discharge $= \left(\frac{.84}{12}\right)^2 \times .7854\sqrt{2g \times 1.057} = .0317$ cu. ft. per sec.

Coefficient of discharge $= \frac{.01975}{.0317} = .624.$

Coefficient of contraction $= \left(\frac{.7}{.84}\right)^2 = .694.$

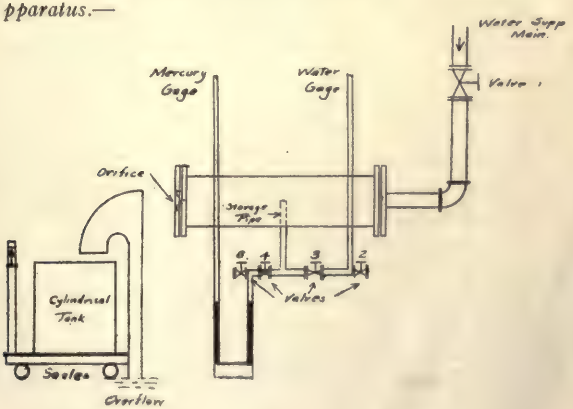
Conclusions.—The value of the coefficient is higher than those values given in the book. The results of Run No. 2 do not seem to be consistent with the results of the other runs, indicating the probability of error.

[Three data sheets have been omitted in editing.]

4. The Orifice

Object.—The object of this experiment is to determine the coefficient of discharge from a standard orifice.

Apparatus.—



The general outlay of the apparatus used in this experiment is as shown in the above figure. Water is allowed to enter through valve (1) from the supply main. The water flows into the storage pipe, through the tank, and over the orifice into the cylindrical tank, which is placed on scales so that the water discharged may be weighed. The elevation head of the water is obtained by the water gage reading, but in case this head exceeds the maximum gage reading, valve (3) is closed and valve (2) is opened, so as to allow the water to drain out. Then valve (4) is opened, which connects with the mercury gage used in the determination of the larger heads. With the data as shown on the accompanying data sheets, the coefficient of discharge may be determined by the formula:

$$q = cF\sqrt{2gh}$$

where q is the rate of discharge,

c is the coefficient of discharge,

F is the area of orifice,

and h is the head.

Method.—The first thing done in this experiment was to remove the orifice from the drum and measure its diameter; this we found to be .84 in. After replacing the orifice, we closed the mercury valve and opened the main supply valve, filling the tank or drum until the water flowed from the orifice. Then by means of a small cock under the drum the water level was lowered until it was just level with the lower edge of the orifice. The gage was then read, and by adding one-half the diameter of the orifice, the height of the center of the orifice was thus computed. Then the air cock on top of the drum was opened, and water allowed to enter the drum through the supply main until water came out of the air cock, thus showing that all air was removed from the drum. Then the main supply valve was opened so as to allow more water to enter until the desired head was obtained for the first run. The run was then taken, observations of the head on the water gage being made every minute and the water being allowed to discharge into the tank on the scales, where it was weighed after each run. Owing to a break in the mercury tube the mercury gage could not be read so as to get a check on the readings for determining the heads. During each run the diameter of the jet just outside the orifice was calipered. It is difficult to determine this dimension exactly, but, as shown on the data sheet, the diameter remained practically constant for varying heads.

The diameter of the drum (inside) was 8 inches. The style of the orifice was circular.

Sample computations:

Initial gage reading, bottom of orifice = 3.705′
½ diameter of orifice = .035′
Elevation of centre of orifice = 3.740′

Actual rate of discharge,

$$\frac{367.5}{62.4 \times 5 \times 60} = .0196 \text{ cu. ft. per sec.}$$

Theoretical rate of discharge,

$$q = F\sqrt{2gh} \quad F = \frac{\pi}{4} \times .0049$$

$$= \frac{\pi}{4} \times .0049 \times 8.03\sqrt{1.04} = .0316 \text{ cu. ft. per sec.}$$

Coefficient of discharge,

$$c = \frac{.0196}{.0316} = .62$$

Mean velocity of approach $= \dfrac{q}{\text{drum area}}$.

$$v = \frac{.0196}{\left(\frac{8}{12}\right)\frac{2\pi}{4}} = .0561 \text{ ft. per sec.}$$

Velocity head $= \dfrac{V^2}{2g}$

$$h = \frac{(.0561)^2}{64.4} = .0000488 \text{ ft.}$$

Coefficient of contraction: $\dfrac{\text{area of jet}}{\text{area of orifice}} =$

$$\frac{\frac{\pi}{4} \times \left(\frac{.68}{12}\right)^2}{\frac{\pi}{4} \times \left(\frac{.84}{12}\right)^2} = \frac{(.68)^2}{(.84)^2} = .655$$

Practically constant.

(Three data sheets have been omitted in editing.)

5. Boiler Inspection Report

Madison, Wisconsin,
May 15, 1916.

To the Board of Regents,
University of Wisconsin,
Madison, Wisconsin.
Gentlemen:

In compliance with your written order of April 5, 1916, I have inspected the Number 9 350 horsepower Babcock and Wilcox boiler unit fitted with a Roney Mechanical Stoker, which is located at the new heating station. A careful inspection was made in order to ascertain its present condition and to determine whether or not immediate repairs are necessary. The examination did not include any efficiency tests, but consisted simply of an examination.

The drum was thoroughly examined from the inside. Above the water line the surface of the drum was slightly pitted as was the dry pipe. This pitting was less than would be expected and was not enough to impair the strength of the drum or dry pipe. There was considerable scale deposit below the water line, indicating that the quality of feed water used might be improved. This scale was $\frac{1}{32}$ of an inch thick in some places. The condition of the riveting throughout the drum was good. The water pipes leading from the drum were in good condition and very clean.

The vertical headers were then inspected. Their outward appearance was not very good; it was evident that several hand holes were leaking and allowing the steam to escape and to deposit scale on the outside of the headers. Several hand holes were removed, and their gasket packing was inspected. The gaskets used consisted of forms of tin in which was contained asbestos. The use of this particular type of gasket accounts for the leaks. The pipes as seen from the open hand holes were clean and in good condition, an indication that the scale deposit is being removed at regular intervals.

The mechanical stoker was in good operating condition as were the coal chute and ash removers. In fact, from outward appearances the complete fire box seemed to be in good condition. However, an inside inspection of the fire box brought out the fact that the grates were in poor condition. The replaceable units of the grates were all worn out, which will, of course, seriously impair the satisfactory operation of the stoker. The fire brick lining in the fire box was in good condition.

In conclusion I would say that the Boiler is in fairly good operating condition. The following changes are recommended:

1. That the scale deposit in the drum be removed and that steps be taken to improve the quality of the feed water used.

2. That the hand holes in the header be removed, and that soft lead gaskets be substituted for the tin and asbestos ones now in use in the header holes.

3. That the grate be repaired by putting in a complete set of replaceable units.

The above repairs, which could be made at a small cost, would place the Boiler in first class condition.

Respectfully submitted

(Sig.) R. J. Bell

6. Brief Report on Geology Trip to the Dells of the Wisconsin

Object of the Trip.—The object of the trip was to ascertain the composition, structure, and causes therefore, of the rock composing the gorge known as the "Dells of the Wisconsin."

General Layout and Description.—The portion of the Wisconsin River known as the Dells is that part of its course where the water, which has a width of several thousand feet upstream, is suddenly forced to go through a gorge which varies from 75 to 200 feet in width. The total length of the Dells is about four miles. The walls on either side are between 50 and 75 feet high. The depth of the water was not ascertained but must be considerable throughout the gorge. The topography is essentially young in character.

Composition and Structure of the Rock.—The rock is composed almost entirely of sandstone. Bedding is practically horizontal, indicating no extensive earth movements since its formation. The layers of stone are quite thin and joints are very prominent, giving rise to numerous canyons, which in some cases have smaller tributary canyons.

Special Features.—Cross-bedding of the sandstone is quite prominent.

The canyons are in most cases practically at right angles to the river, a condition which is due to the fact that they were formed by joints.

Pot-holes, formed by the cutting action of the sand in whirlpools, are found in some of the canyons.

At the place marked *A* on the map is a former channel of the river, now dry except at periods of high water.

Cause of Topography.—The cause for this gorge was the blocking of the Wisconsin River by glaciers at a point somewhat north of the

Dells, which forced it to change its course. The new course led across this outcrop of comparatively soft sandstone, and the water wore its way down through the stone. The canyons leading away from the main gorge were started by joints in the rock, through which water from the surrounding country flowed into the river, and in so doing, further increased the depth and width of the fissures.

PROFESSIONAL REPO

[The variety of forms of professional re
the length of many of them has precluded
tion here of a representative selection. The
will serve as examples of certain types. They sho
supplemented in class discussions by municipal, pu
service, and other easily secured reports.]

1. Letter Reporting a Test

[The following is a very common type of report,—the letter to a superintendent from his subordinate reporting a test and making recommendations based upon it. A great many professional reports take the form of letters; long ones addressed to boards of directors, committees, or similar bodies usually have a "Letter of Transmittal" prefixed to them. The letter is addressed to *Building* because it was sent from one office to another within the same building.]

[*Letterhead with place of writing*]

March 2, 1917.

Mr. J. L. Adams, E. E. D.,
Building.
Dear Sir:

This morning voltage readings were taken at the Johnson Company in Johnsonville as follows:

Voltage dropped from 222 to 178 on starting, with the motor on one phase of the power circuit. On a second trial with the same connections and taking 15 seconds longer to start, the voltage dropped from 222 to 198. The lower reading was obtained at the instant that the short-circuiting clutch went in.

On the opposite phase with the same conditions as above the voltage range was from 222 to 202.

Readings were then taken when the motor was started with the voltmeter on the lighting circuit. Here the voltage dropped from

110 to 100 when the clutch went in 20 seconds after the motor was started. When 30 seconds was used to start the motor, the voltage range was from 110 to 103.

Readings were also taken at meter number 9830 on a secondary system fed from transformers on the Albany Road. Here the voltage dropped from 109 to 102 during the starting of the motor.

It seems evident from the above tests that the Johnson Company have been responsible for the lights dipping at Edmonds' Hotel, and on other installations on the Johnsonville circuits. In the case of the Edmonds' Hotel this would be more noticeable because the installation is on the same primary tap as the motor.

Attached is a requisition for doing away with this condition by running primary to the Albany Road.

Respectfully submitted,
(Sig.) J. R. MEARS.

2. ABSTRACT OF REPORT OF COMMITTEE ON STREET LIGHTING

[The following is the abstract preceding a seventeen page committee report read recently at a convention of the National Electric Light Association. It should be noted that it provides at a glance an idea of the scope and content of the report and that it was therefore very useful to members who had not the time to read the entire article.]

ABSTRACT

The primary purpose of street lighting is to promote facility and safety of movement during the hours when sunlight is not available, and the report is therefore confined to the technical problems encountered in meeting these requirements.

In Section I the relation of street illumination to artificial lighting in general is pointed out and the historical development of street lighting as a police aid is discussed.

In Section II the science of illuminating streets is treated under the following heads: Intensity, Distribution and Direction of Light; Glare; Lamp Sizes; Locations and Fixtures.

Section III consists of a technical description of various systems of distribution.

In conclusion, the Committee reports that in addition to the foregoing technical matters, it has considered the questions of standard forms of specifications and contracts together with that of costs, but that these matters can not be made a part of the report at this time.

3. (Table of Contents of) Comparative Tests of Run of-Mine and Briquetted Coal on the Torpedo Boat *Biddle*[1]

By Walter T. Ray and Henry Kreisinger

[The following table of contents is reprinted to show the plan of a government report based on a series of comparative tests. Other outlines of similar reports are reprinted on pages 41–42.]

[1] Bureau of Mines, *Bulletin* 33 (1911). Reprinted by permission of the Director of the Bureau.

ILLUSTRATIONS

[Omitted in reprinting]

TABLES

[Omitted in reprinting]

4. The Rate of Burning of Fuse, as Influenced by Temperature and Pressure[1]

By Walter O. Snelling and Willard C. Cope

[The following is the *Introduction* of a twenty-five page report of an investigation conducted for the Bureau of Mines. The *Table of Contents* of the report will be found on page 41. It will be noted that the *Introduction* is a general clearing ground for the rest of the report, which consists of an account of the various tests made and a statement of the conclusions drawn from them].

INTRODUCTION

Miners' fuse, known also as "safety fuse," "running fuse" and "Bickford fuse," consists essentially of a core of gunpowder surrounded by protective wrappings or coatings. It is used in blasting as a gunpowder "train" for transmitting ignition to the charge of explosive, and its purpose is to provide a time interval between the lighting of a "shot" and the explosion of the charge.

Such fuse best fulfills its purpose when its rate of burning* is uniform, so that the interval between the moment of lighting the "shot" and the moment at which the "shot" explodes is definite for any given kind and length of fuse. In mining operations it is assumed that the fuse used burns at a regular and uniform rate, and, believing this, the miner in his daily work cuts off such lengths of fuse as should give the particular time intervals desired.

There are, however, conditions that cause variations in the rate of burning of fuse, some causing a marked retardation and others causing a decided acceleration. Hence it has seemed necessary to

[1] *Technical Paper* 6 (1912) of the Bureau of Mines. Reprinted by permission of the Director of the Bureau.

* In this paper, the rate at which fuse burns is expressed in units of time as "30 seconds per foot," and not in units of length, as "2 feet per minute," though the latter form is more in accord with ordinary usage in describing speed or motion. The reason for using the form "seconds per foot" or "seconds per meter" is that the time in which a given length of fuse burns is the information the miner desires. [Authors' note.]

powder surrounded by the spinning threads and first countering, as just described.

Fuse is divided into three main classes according to the nature of the work for which it is intended. Fuse of class 1 is suitable for dry work, such as stump blasting and quarrying. Fuse of class 2 is intended for damp or wet work, as in coal mining, or in surface work where mud, rain, or dampness is encountered. Fuse of class 3 is suitable for very wet work, such as may be necessary in tunneling, shaft driving, etc.

Cotton, hemp, and single-countered fuse are of the first type, and consist of "raw fuse" that has been drawn through a bath of waterproofing material and finished with whiting, talc, or some similar substance to prevent the separate loops of a coil from sticking together. In cotton fuse the spinning threads as well as the countering are of cotton instead of jute. Single-tape fuse and double-countered fuse are of the second type, and consist of raw fuse that has been twice coated with waterproofing material, double countered or taped and finished like fuse of type 1. Double tape, triple tape, gutta percha, and taped double-countered fuse belong to the third type. These consist of raw fuse that has been coated with waterproofing material and taped or double countered, and then finished with a coating of black varnish and whiting or talc, etc., or with a heavy coating of white china clay mixed with glue to form a paste.

Composition of Fuse Powder

The gunpowder which forms the core of safety fuse is usually in very fine grains. At times the waste from sporting powder is used in the preparation of fuse, but usually a special powder is made for this purpose. An analysis of a sample of fuse powder gave the following results:

Analysis of fuse powder

Moisture	00.63
Nitrate of potash	74.42
Sulphur	11.96
Charcoal	12.99
	100.00

The size of the grains of this powder as determined by a sieve test was as follows:

Size of grains of fuse powder

Caught on 40-mesh sieve	7.7
Caught on 60-mesh sieve	40.53
Caught on 80-mesh sieve	13.95
Caught on 100-mesh sieve	27.50
Through 100-mesh sieve	10.31
	100.00

5. Report on the Proposed Hydro-electric Developments on the Peshtigo River at High and Johnson's Falls[1]

Daniel W. Mead
Consulting Engineer
Madison, Wis. Chicago, Ill.

[The following is the first part of a typical report addressed by a consulting engineer to the company which has engaged his services. The name and address of the president of the company and the name of the company in the Letter of Transmittal have been changed; otherwise the report has not been altered. The number of pages reprinted in proportion to the total number may be seen from the Table of Contents.]

TABLE OF CONTENTS

[1] Reprinted by permission of Professor Mead.

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TABLE OF CONTENTS

[1] Reprinted by permission of Professor Mead.

APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E

[A list of illustrations and diagrams has been omitted in reprinting.]

LETTER OF TRANSMITTAL

Madison, Wisconsin, December 9, 1908.

Mr. R. G. Owens, President,

Midland Hydro-Electric Power Company,

York, Wisconsin.

Dear Sir: I have been requested by the Board of Directors of the Midland Hydro-Electric Power Company to report on the proposed hydro-electric developments on the Peshtigo River at High and Johnson Falls, and the transmission to Green Bay, Wisconsin, of the power so generated.

In making this report I have endeavored, as far as practicable, to simplify all technical descriptions and details and to explain all deductions in such a manner that any business man may be able to fully understand the facts in the case, to follow the argument, to understand the basis of the conclusions and, hence, to form his own opinion as to the validity of the same.

While every engineering problem must require for its correct solution the application of technical knowledge and experience, yet a correct solution must be based fundamentally on sound reasoning and business principles. It has long been my opinion that if such a problem, together with the data on which its solution must be based, is clearly set forth, the validity of the conclusions regarding the same will become apparent and will appeal to the judgment of any thinking business man. While technical training is required to thoroughly understand the details of such a problem, yet the general proposition itself, if worthy of consideration, must appeal to sound common sense and business judgment; and if the entire proposition is carefully set forth, it is seldom necessary to rely wholly on the judgment of the expert in such matters.

I trust in the following pages I have been able to so completely cover this subject as to make the reasons for and validity of my recommendations fully apparent after a careful reading of this report.

Very respectfully,
Daniel W. Mead,
Consulting Engineer.

Location

The proposed hydro-electric installations considered in this report are to be constructed at High Falls and Johnson's Falls on the Peshtigo River in Marinette County, Wisconsin, about fourteen (14) miles northwest of the Village of Crivitz or the Chicago, Milwaukee and St. Paul Railway Station, known as Ellis Junction. The sites of these developments are in the northeastern part of the State of Wisconsin just north of a line due west from Marinette, and about sixty (60) miles northwesterly from the City of Green Bay. (See Diagrams I and III.)

Field Work

Preliminary Examination and Report.—I first made an examination of this locality in the early spring of 1906, and caused a preliminary topographical survey to be made of the river from a point about one (1) mile below Johnson's Falls to Caldron Falls, about thirteen (13) miles farther up the river. At that time no gagings had been made of this stream but, based on the preliminary survey together with the flow records of adjacent rivers, a report was made under date of April 17, 1906, which included an estimate of the amount of power that might be developed and the approximate cost of such development.

Canal Project.—Following this report, a preliminary survey was made for a possible canal route from a point above High Falls to the foot of Johnson's Falls, to determine the feasibility of developing these two falls in a single installation. Such a plan was found to be feasible, and a preliminary report to this effect was duly made. The laws of Wisconsin, while providing for the condemnation of land for flowage purposes (see Appendix A), make no provision which will permit of the diversion of a stream from its natural bed without the consent of the riparian owners between the points of diversion and return of the waters. As such consent could not, in this case, be obtained, the canal project above outlined has not been further considered.

Establishment of Gaging Station.—In the latter part of August, 1906, a gaging station was established on the Peshtigo River near Herman's farm, about six (6) miles above the Village of Crivitz. Daily readings of the gage have been made from that date to the present time.

Topographical Survey.—In the fall of 1906 a detailed topographical survey of the Peshtigo River was made from a point about one mile below Johnson's Falls to a point above Twin Falls, and to a contour height of 1120 feet above sea level in order to obtain a basis for the preparation of plans for the power development. This survey has since been supplemented by a further survey extending the information to a higher elevation (elevation 1130) in order to determine the feasibility of raising the dam and impounding a greater amount of water for storage purposes. On the basis of these examinations and surveys, numerous maps and plans have been prepared and are now on file at this office.

THE PESHTIGO RIVER

The drainage area of the Peshtigo River lies in the northeastern part of Wisconsin, within the glaciated area which contains the numerous small lakes for which Wisconsin is famous. Its location relative to the other drainage areas of the State is shown on Diagram No. 1, and its area above the points considered in this report is shown on a larger scale on Diagram No. II. The location of the drainage area relative to the Menominee and Wisconsin Rivers, with which its flow is compared in this report, is shown on Diagram No. III.

In Bulletin No. XX of the Wisconsin Geological and Natural History Survey, entitled "Water Powers of Wisconsin," Professor

L. S. Smith thus describes the Peshtigo River: "The drainage area of the Peshtigo River includes 1123 square miles with an extreme length of 80 miles and an average width of only 14 miles. The upper two-thirds of its length is in the pre-Cambrian regions, while in the lower third it crosses successively the Potsdam sandstone and the lower magnesian and Trenton limestones. The most important falls and rapids are all in the pre-Cambrian regions. Because of the narrow watershed, the Peshtigo tributaries are of small extent.

"The Peshtigo River rises in the highest land of Northern Wisconsin. At Crandon the river has an elevation of 1620 feet above the sea. In a length of about 94 miles it descends 1040 feet, emptying into Lake Michigan (Green Bay) about seven miles south of Marinette. This average gradient of 11 feet per mile gives rise to more and larger rapids than any other river in Wisconsin. This fact together with the usual high and rocky banks insures numerous water powers. The relatively small drainage area is more than offset by the size of the rapids."

The portion of the river to which the power development herein considered is more directly related, lies between the foot of Johnson's Falls and the foot of Caldron Falls about thirteen miles above. The fall between these two points is 130 feet, most of which it is intended to utilize in the proposed power developments.

A profile of the river between the points named is shown on Diagram IV, and a map of the river, on a larger scale between the points mentioned, is shown on Diagram V.

The legislative act under which it is proposed to carry out the improvement was approved April 26, 1899, and published April 29, 1899, and is given in full in Appendix B.

The Power of a River.—The power of a river depends upon two factors, viz., the head or fall that can be developed and maintained at the point of development, and the flow or quantity of water that is available for power purposes at the same point. These factors will vary considerably at different times during each year.

Head.—The head will commonly decrease during high water, due to the backing up of the tailwater or water below the dam. Under low water conditions, when storage immediately above the dam is used, the head will frequently decrease as the pond or reservoir is drawn upon for an extra supply of water during seasons in which the natural flow of the stream is not sufficient for power purposes.

Flow.—The flow of a stream will vary from the extremely high maximum flows during floods when a superabundance of water is available, to the extreme low flows which obtain both in the dry season of summer, during which most of the rainfall is utilized in plant growth, and during the extreme cold seasons of winter when the springs are frozen and the flow is frequently greatly reduced on this account.

A water power development to be commercially satisfactory must usually be such as will furnish constant and continuous power under all the conditions by which its use is modified. The broadest possible knowledge of the stream flow is therefore essential in order to determine with accuracy the continuous power that can be developed and sold to economical advantage.

The most desirable information concerning the flow of a stream in relation to the development of its power is the accurate measurements of the flow of the stream itself at the point at which it is to be developed. For a complete knowledge of the subject it is necessary that these gagings be continued not only throughout the varying conditions of a single year, but that they shall also be continued through a series of years during which all of the modifying conditions which influence and control the flow shall have reached the extremes to which they are subjected. It is very rare that such complete data are available and in almost every case where water power is to be developed, it becomes essential to utilize information more or less limited in extent and by the careful consideration of other data to so supplement and extend the observations that correct conclusions can be drawn for all conditions which are likely to obtain.

All factors in the problem must be carefully examined and considered if a complete knowledge of the power of a stream and the variations to which it may be subject are to be fully known and appreciated.

CHAPTER X

BUSINESS LETTERS

Introduction

A type of composition which the young engineering college graduate is certain to be called upon to write is the business letter. Indeed, business letters and reports are more than likely to form the bulk of his writing for the first few years and perhaps even for the whole of his professional career. With the great increase in the amount of business done by correspondence has come in recent years more attention to the art of business letter writing. Business houses and all companies doing business by correspondence have found that poor, slovenly letters do not pay, and that careless letters lead too often to irritation, misunderstanding, loss of trade, and even litigation. Accordingly, the best companies have systematized carefully the work of writing their letters and have tried to create and follow a high standard. It therefore behooves the young employee of an engineering firm to know something of the best practice in business letter writing and to keep his official correspondence up to as high a standard as possible.

In this brief chapter no attempt will be made to give more than a few comments on the general qualities of good business letters, the accepted forms, and the make-up of a few of the types which engineers are most likely to write. Engineering students who expect to engage in the commercial work of their profession, and who therefore desire to study commercial correspondence further, are referred to the many excellent books on the subject.

Many of the practices of modern business correspondence have resulted from the necessities of standardizing letter forms and thereby economizing time and energy. For it should be remembered that a business letter, unlike a social letter, must be regarded from two points of view; not only is it the vehicle of communication between correspondents, but it also provides, either in its original form or in carbon copy, a permanent record of the business transaction involved. In modern practice all business letters received and carbon copies of all letters sent out are classified, usually by subject, and carefully filed. As these files are constantly referred to for data, it is apparent that for ease of filing and convenience of reference uniform practices must be followed. For this reason a standard size of paper is employed, letters are written on only one side of the sheet, the date, inside address, subject of the letter, and other details are always included, and certain other standard practices are regularly followed. Uniformity in these particulars results in maximum convenience and economy for both correspondents. The following qualities of good business letters and the details of their form are not, therefore, accidental, but result almost without exception from the general demands of usefulness and economy.

Qualities of the Good Business Letter

1. *Good Appearance.*—A business letter is the representative of the firm which sends it. It is as important, therefore, that it present a neat, trim appearance as that

an employee representing the firm be well groomed. The slovenly letter, like the slovenly salesman, is not pleasant to meet and does not merit any particular attention.

Good appearance means, ordinarily, that the letter must be typewritten; the days of the old, half legible scrawl have passed. In the matter of spacing tastes differ; the usual practice, however, excepting in very short letters, is to single space the lines within the paragraph and to double-space between paragraphs.

The neat letter will, furthermore, be well balanced on the page; that is, it will not be crowded into a part of the page, but will be written with uniform margins on all sides.

In the matter of letter-heads good taste dictates simplicity. The printing at the top of the letter should be well arranged and neat in appearance. It is not good form to crowd the top and left-hand margin with advertising matter, which is almost certain to give the page a messy appearance and to detract attention from the subject matter of the letter.

The paper should be white, of good weight, and of the regulation letter size (8½ by 11 inches). The practice of writing short letters on half-sheets is disappearing because of the inconvenience of filing and handling sheets of varying sizes.

In general, the letter should reflect in appearance the good taste and care of the writer and of the firm which he represents. The question of good form is, finally, too important a matter to be left entirely with the stenographer.

2. *Brevity.*—The necessity for economizing the valuable time of both writer and reader dictates that the

business letter be as brief as is practicable. Brevity does not mean crude curtness; it means simply stating the subject of the letter promptly and continuing without rambling. Ordinarily a letter should be confined to a single page, although there are, of course, times when it must be longer. Letters which contain a very slight idea enshrouded in a mist of words cause amusement where they do not create irritation.

3. *Completeness.*—A letter should never be so brief that it is incomplete in content. The writer should invariably be careful to include all information which his correspondent will need. Failure to do this will result in the necessity of further correspondence and in consequent delay, inconvenience, and economic loss.

4. *Carefulness.*—In addition to being complete, the information contained in a letter should be accurate. Quotations, specifications, details of an order should all be carefully checked over, for mistakes are costly. Furthermore, the writer of a business letter should be careful never to commit to writing any statement which he is not willing to stand by, for once having made an unequivocal promise in a letter, he can not honorably repudiate his agreement, even if he might legally do so.

5. *Clearness.*—A business letter is worthless unless it is understandable. For this reason it should contain no vague or ambiguous statements. Good English is as important in a letter as in any other form of composition, perhaps even more so since here the evil results of incoherent sentences are likely to be certain and immediate.

6. *Courtesy.*—Good business relations can be established and maintained only upon a basis of gentlemanly conduct and unfailing courtesy. Irritation, pride, and anger expressed in business letters are seldom war-

ranted and more seldom accomplish their ends. It is well always to remember the point of view of the other man and to treat him with the dignity and decency which you would expect him to show towards you.

7. *Dignity.*—Courtesy in a business letter does not mean undue familiarity. The average reader of a business letter resents being addressed by a stranger or mere business acquaintance as though he and his correspondent were bosom friends as much as he resents being slapped on the back or called "old fellow" by a person whom he has just met. Moreover, he is very likely to suspect the good taste or the motives of such a writer. A uniform tone of dignity and self-respect in business letters is much to be preferred to a blatant and vulgar over-desire to please.

8. *Individuality.*—The "personal touch" has become a familiar phrase in business correspondence. It means that the business letter need not be so formal and regular as to submerge entirely the individuality of the writer. It means further that every correspondent likes to feel that the letter addressed to him is meant for *him* and is not identical or almost identical with those sent to scores of others. A part of this individuality may be secured by following the prevailing practice of avoiding stock phrases and formulas, but much of it lies behind the mere form and phrasing, in the personality of the writer. The importance often attached to this quality is illustrated in an incident which occurred not many years ago in the Broadway offices of a large manufacturing company. A young Sibley College graduate had been for two months in charge of a minor department which demanded considerable correspondence. He was priding himself upon the increasing resemblance between his

letters and those of his predecessor in the position, and was, therefore, much surprised when his chief said to him one morning,

"Mr. Johnson, what is the matter with your letters? I have been reading some of them lately, and they don't suit me at all."

"Why, sir," was the reply, "I am sure that they are just like those Mr. Billings wrote before I took charge of his work."

"Of course they are, and that's just what's wrong with them. He is a 'rubber-stamp' man, and I thought when I put a college graduate in his place that the letters would show a lot more color and individuality. What is your college training good for? Now throw your rubber-stamp into the scrap-basket, and write me some real letters."

Shortly after this incident the young college man epitomized his lesson in a letter to a friend in the following words:

"A business letter should be clearly distinctive of the writer, and its form should vary constantly, or he will get into a rut and not write a college man's letter. Rigid forms and phrases are good enough only for rubber-stamp clerks."

Form of the Business Letter

A sample business letter arranged in accordance with the best prevailing form is shown on page 398. For convenience of reference the different parts have been numbered and labeled. The suggestions for good form which follow should not be regarded in all cases as indicating invariable practice but as representing what an examination of several hundred business letters seems to show are the best usages.

```
                                        [1. Heading]
                                        16 Johnson Court,
                                        Madison, Wisconsin.
                                        May 6, 1916.
    [2. Inside Address]
Marshall-Blakemore Manufacturing Company,
Milwaukee, Wisconsin.

    [3. Salutation]
Gentlemen:
                          [4. Body of Letter]

    I have been informed that each year you take into
your employ a number of engineering college graduates,
and I should like, therefore, to file my application for
a position with you.

    My practical experience consists of four months, June
to September, 1913, with Judson and Fuller, Consulting
Chemists, 145 Lambert Street, Chicago, making the tests
included in their report to the Association of Commerce
on the abatement of the smoke nuisance and the electri-
fication of the railway terminals.

    I shall be graduated from the University of Wisconsin
in June of this year with the degree of B. S. in Chemical
Engineering.

    By permission I refer you to the following gentlemen:

    Mr. William B. Judson, Consulting Chemist,
        145 Lambert Street, Chicago, Illinois.

    Professor R. J. Bedford, University of Wisconsin,
        Madison, Wisconsin.

    Mr. Raymond T. Edwards, Cashier of the Third National Bank,
        Madison, Wisconsin.

    If you should care to have a personal interview with
me, I can go to Milwaukee at any time which suits your con-
venience.

                                        [5. Complimentary close]

                                        Very truly yours,

                                          [6. Signature]

                                        (Sig.) J. B. Adamson.
```

1. *Heading.*—The heading consists of the writer's address, where this is not given in the letterhead, and the date. Both address and date are necessary and must be

supplied in all cases. Omission of the writer's address makes a reply difficult, if not impossible, and the date must be used in interpreting the content of the letter. In the arrangement of the lines of the heading the practice of making the left edge vertical, as shown in the model, instead of slanting downwards, seems to be usual. Abbreviations should ordinarily not be used; if they are used, they should conform, in the case of states, with the post-office regulations and in the case of months with standard usage. Dates should not be abbreviated as follows: 2/5/'17, for February 5, 1917.

2. *Inside Address.*—The inside address preserves some very necessary information after the envelope has been destroyed. It is needed for a complete understanding of the letter and sometimes for a correct fixing of responsibilities. The title of the person or firm should be given excepting where it is regularly omitted in advertising and correspondence by the business house addressed; *e.g.*, Dr. John B. Evans, Edward N. Marshall, Esq., Messrs. Bolton and Smith, The Globe Milling Company. A letter addressed to a firm but intended for an individual member or employee should be addressed as follows:

The Globe Milling Company, St. Paul, Minnesota,
Attention: Mr. J. R. Smith, Purchasing Department.

Practice differs in the matter of indenting successive items of the address or of writing all the same distance from the left hand margin. The latter practice saves time in typewriting, and is, perhaps, more frequently followed. In any case the inside address should conform in this detail with the *heading*.

3. *Salutation.*—In the best business letters the follow-

ing forms are used in the salutation: Dear Sir: Gentlemen: Dear Madam: Ladies:. Sir: is usually used only in the government service in addressing a superior, or, sometimes, in addressing an editor. Dear Sirs: is not in good usage; My dear Sir: is often condescending in its implication.

The colon should be used with the salutation.

4. *Body of the Letter.*—To comment fully on the body of the letter would be almost to give a complete course in business correspondence and in English composition. What follows is, therefore, merely an attempt to emphasize certain essentials.

(*a*) *Content.*—A business letter should ordinarily deal with only one subject, excepting where it is an omnibus letter replying to several questions asked by the correspondent. The letter which takes up more than one subject is difficult to file without cross-reference even if it does not have to be sent from one department to another for answer. The subject of the letter should be definitely stated in the first or second sentence. Sometimes it is put, like the title of an article, in a separate caption just under the letterhead, a practice which assists greatly in filing and reference.

(*b*) *Paragraphing.*—The usual principles of paragraphing do not apply to the business letter. Here each item is for distinctiveness paragraphed separately so that even a comparatively short letter may have several paragraphs. For example, a letter reporting to the shippers the receipt of a damaged shipment might be paragraphed thus:

Paragraph 1. Notice that shipment number so-and-so arrived on such-and-such a date in bad order.

2. Description of the extent of the damage.

3. Statement of the probable responsibility of shipper or carrier.

4. Statement of what adjustment the receiver of the damaged shipment regards as satisfactory.

Other examples of paragraphing will be found in the specimen letters on pages 409–420.

(*c*) *Beginning.*—The initial sentence is as difficult to write as it is important. Unless the letter opens a correspondence, the first sentence should usually contain a reference to the date and subject of the letter being answered, or to the telegram, telephone message, conversation, or other transaction which occasioned the letter. This reference provides for the reader an immediate connection with the subject. The first sentence may also contain a statement of the subject of the letter; if it does not, the subject should almost always be stated early in the letter. Occasionally, as in a collection letter, the writer may wish to approach the real subject easily and gently; and he will therefore begin with a matter of minor importance and gradually open into the more important matters.

The initial sentence may contain the necessary elements of contact point and subject announcement without being a stiff formula. Formal beginnings like the following should be avoided:

"Yours of the 3rd inst. at hand and contents carefully noted. In reply would say, etc."

"Referring to your favor of March 6, etc."

Beginnings which are more easy, graceful, and natural, like the following, give the information necessary and are at the same time much pleasanter to read:

"In reply to your application of January 16 for a position with us, we are sorry to say that our firm does not make a practice of employing in its shops men who have not had some experience in machine-shop work, etc."

"After our telephone conversation of last Monday, I immediately investigated with Mr. Jones the condition of the Briar Street Theatre and found the following details which do not conform with the building regulations, etc."

(*d*) *Conclusion.*—Between the initial and the concluding sentences of a business letter, form and content will naturally depend largely upon the subject matter. At the end the best rule to follow is: When through, stop. A conventional, meaningless, and empty tailing off should be avoided. This restriction applies particularly to the formal participial phrase ending, which is at best flat and tasteless, and which is often bad in rhetoric. The addressee should not be insulted by such a conclusion as "Hoping that this matter will be given your prompt and careful attention," (as though the writer had some doubt), or put under obligations by "Thanking you in advance, etc.," or simply irritated by "Trusting to hear from you at your earliest convenience," etc.; nor should the writer "remain" or even "beg to remain." The modern practice in respect to all these ancient phrases is to discard them for good, plain, simple English.

5. *Complimentary Close.*—The best forms for the complimentary close are: "Yours very truly," or Very truly yours." "Respectfully yours" may occasionally be used in addressing a superior, and "Respectfully submitted" in making a report. "Yours truly" is somewhat blunt; "Yours for business," and the like, are blatant and vulgar.

6. *Signature.*—Little need be said of the signature

excepting that it should be so legible as to leave no doubt as to the identity of the writer. Where a representative of a firm signs a letter for his company, the following practice prevails:

DANVILLE-JONES ELECTRIC POWER COMPANY
BY E. R. JONES, PRESIDENT

Frequently the name of the writer is typed in, the signature being made above, below, or even through the typing. This practice gives the full name on the carbon copy and also insures a correct reading of the signature.

Practices and Phrases to be Avoided Throughout.—The subject of the verb should not be omitted; *e.g.*, "Received a call from your representative, Mr. Smith, yesterday and looked over some of his sample fixtures. Believe that we could use some of the drop-lights, etc."

The participial endings, "Hoping . . . ," "Trusting . . . ," "Thanking you in advance . . . ," "Assuring you . . . ," etc., should not be used.

Abbreviations should in general be avoided, although for the states, the months, and in a few other cases they are permissible. The forms "ult.," "inst,." and "prox." should not be employed instead of the specific name of the past, the present, and next month respectively.

The following words and phrases should not be employed: "We beg to remain;" "as per your request;" "contents carefully noted;" "enclosed please find;" "we note you state;" "each and every one;" "in reply would state;" "yours," or "your favor," for "your letter;" "advise" for "inform;" "state" for "say;" "per" for "by" (in a signature); "same" for the specific substantive, and, in general, any worn-out, "rubber-stamp" word or phrase which is meaningless, empty, and colorless, and which can either be omitted entirely without loss to the letter or should yield to a more natural and individual word or phrase.

Types of Engineering Letters[1]

Letters written by employees of engineering companies usually take three forms: (1) correspondence of a more or less social character between companies and officials of companies, such, for example, as invitations, letters of congratulation, etc.; (2) staff correspondence between employees of the same company; and (3) regular business correspondence with other companies or with individuals. Of the first class nothing will here be said; of the second, only such comments will be made as apply also to letters of the third class; of the many different types belonging to the third class, it will be necessary to select for comment only a few of the more common. These comments will be preceded by a fuller comment on the letter of application, the type with which students are usually most concerned.

1. *Letters of Application.*—The letter of application is usually the first type of business letter which the engineering college graduate is required to write. Most engineering concerns request the filling out of an application blank, but the original letter applying for the position is filed and is in many cases important; it should therefore be carefully written. The letter of application should ordinarily contain the following elements: (*a*) point of contact; (*b*) application for the position; (*c*) statement of

[1] For much of the specific information in this section acknowledgment is made to Mr. P. W. Kinney of Rochester, N. Y., and to Mr. H. W. Watt of the Westchester Lighting Company, Mt. Vernon, N. Y.

qualifications and experience; (*d*) references; and (*e*) arrangement for personal conference.

(*a*) *Point of Contact.*—This begins the letter with a statement of the source of information regarding the vacancy or possible opening; *e.g.*, "In response to your advertisement in yesterday's *Herald* for a skilled mechanic, etc.;" "I learned yesterday from Mr. G. E. Edwards, foreman of the Repair Department of the Duluth Motor Works, that you have a vacancy in your machine-shops, etc."

(*b*) *Application for the Position.*—The applicant should not fail to say definitely—as he is frequently likely to do—that he is an applicant for the position. This statement should usually be combined with the sentence containing the point of contact.

(*c*) *Statement of Qualifications and Experience.*—In this section of the letter the writer should be modest but not self-depreciatory. A dignified, impersonal statement of those qualifications which the prospective employer should know and which would prove useful in the position applied for can not fail to be more impressive than statements which are either conceited or self-consciously over-modest. The writer should, on the one hand, give a sufficiently complete statement of qualifications, but should, on the other hand, avoid the self-sufficient inflation often embodied in the familiar "I feel fully qualified to fill the position."

(*d*) *References.*—A good list of references is more important than the applicant usually realizes. The list should possess variety so that while some may vouch for the applicant's technical knowledge and experience, others may certify to his general moral qualifications. The applicant should not list persons who have not expressed their willingness to be written to concerning him, and he should avoid listing persons of prominence or influence who are but slightly acquainted with him. For the reader's convenience each reference should begin a new paragraph. The enclosure of open letters of recommendation collected from friends and teachers is of little value; letters of recommendation should not pass through the hands of the applicant.

(*e*) *Arrangement for a Personal Conference.*—Where a personal conference is expected or desirable, the applicant may suggest that he can arrange to meet his prospective employer at a time to suit the latter's convenience. He should never attempt to set the exact time of the conference; this is the privilege of the person addressed. The applicant may, however, write somewhat as follows: "I expect to be in Chicago next Thursday afternoon, and, if convenient for you, I can arrange to meet you at that time."

The appearance, care, and tone of a letter of application are usually of as much importance as strong qualifications. A slovenly, careless letter, filled with errors, condemns the applicant before the reader reaches the statement of the writer's experience. A letter of application should be comparatively brief; a long-winded self-glorification amuses the reader even if it does not irritate him. Finally, the letter should be individual; no "model" should be followed rigidly. Of several hundred letters of application written recently in a state civil service examination all but half a dozen were almost identical save for the data which they contained; and the half dozen stood out from the others because they revealed personalities behind the written page.

2. *Order Letters.*—The order letter should usually contain: (*a*) the order; (*b*) shipping directions, where they are not already definitely understood; (*c*) date when goods are wanted; (*d*) arrangements for remittance, where this matter has not been previously agreed upon. To facilitate checking, the list of goods should be tabulated, with each item on a separate line. For emphasis each item should be capitalized. The order should be carefully checked over before it is mailed, and a copy of it should invariably be kept.

3. *Adjustment Letters.*—If a shipment is delayed or received in bad order, or if a guaranteed machine breaks down or proves on test to be below specifications in the contract, the person inconvenienced thereby should not blame the shipper or contractor in an angry letter, but should simply lay before him the facts in the case with perhaps a suggestion as to what adjustment will be satisfactory to the purchaser. In reply the writer should express regret at the annoyance which his correspondent has suffered and promise such adjustment as the facts may warrant.

4. *Letters of Instruction.*—Letters of instruction may be addressed to subordinates delegated to carry out certain operations or to customers, consumers, or others not officially connected with the company. All such letters must be absolutely clear. In the case of letters of instruction to outsiders the lack of technical knowledge of the readers must usually be taken into account as well as their peculiar relationship with the writer or with the company which he represents. An individual who has purchased from a manufacturing concern a machine which he is having some operating difficulties with expects and is entitled to a painstaking explanation of

his troubles and clear and complete directions for overcoming them.

5. *Letters of Commendation.*—Practicing engineers are frequently asked to write their opinion concerning men, engineering practices, and apparatus of various sorts. In writing a letter of recommendation for an individual, the writer should be fair but just; he should write exactly what he believes to be the qualifications of the individual for the particular position involved, and his opinion should be based solidly on experience with the subject of the letter and observations of his work. A comment on a technical practice or piece of apparatus should state the experience of the writer with the apparatus, his belief as to the limits of its usefulness, and of its particular adaptability to the work in which it is proposed to use it. The length of a letter of commendation will be dependent upon the subject; but no such letter should fail to contain details which the reader would be interested in or likely to find useful.

SPECIMEN LETTERS

[The following selection of letters is not intended to be completely representative of all types; they are designed merely to provide material for class criticism, and should be supplemented by other student and professional letters. The student letters here reproduced were submitted as "themes" in a regular course; the professional letters were taken from the files of a large engineering company, only such changes in names being made as were necessary to conceal identities. It need hardly be added that the letters are not all "models".]

Student Letters

(1)

1354 Orchard Street,
Madison, Wisconsin,
May 6, 1916.

Mr. W. S. Holmes, Gen. Mgr.,
Merryville Electrical Works,
Merryville, Illinois.

Dear Sir:

I am looking for a position in the Testing Department of Electrical Machinery, and wish to know if you have such a position open at the present time. I am especially desirous of getting the practical experience in the testing of Motors and Generators.

I have completed three years in the Electrical Engineering Course at the University of Wisconsin, and I am fairly well informed on the electrical design and construction of the machines which you manufacture. I have had one year of machine work in the Holt Machine Company of this city.

I should be glad to hear from you or to arrange an appointment at your convenience.

Respectfully yours,
(Sig.) L. M. Kendall.

(2)

638 Riverside Avenue,
Madison, Wisconsin,
May 15, 1916.

Wisconsin Highway Commission,
Madison, Wisconsin.

Gentlemen:

I have learned through Professor T. M. Edwards of this city that there will probably be a vacancy on your force in the near future, and I wish to offer myself as an applicant for the position.

I graduated three years ago from the University of Wisconsin in the Civil Engineering Course, and since my graduation I have had two years' experience in the main drafting room of the Southern Minnesota Public Service Company, and in addition I have been with the Vilas County (Wisconsin) Road Commission, with headquarters at Vilas, for one year. During this last period I did all manner of instrument work, in the field, together with map making and topography work.

Mr. R. L. Lamson of Vilas has expressed himself as being willing to recommend me; and I am also permitted to refer you to Mr. M. I. Maxon, Superintendent K. L. P. S. Co., Terminal Building, Chicago, Illinois.

My address is 638 Riverside Avenue. I shall be glad to keep an appointment at any time that may be convenient to you.

Yours truly,
(Sig.) N. C. Hubbard.

(3)

In answering, please
refer to No. 7576.

198 College Place,
Madison, Wisconsin,
May 25, 1916.

E. H. Sudham and Company,
1476 South Park Avenue,
Chicago, Illinois.

Gentlemen:

Please send me at once via American Express, charges prepaid, the following:

No.	Size.	Kind.	Cat. No.	Price.	Total Price.
12–	500 cc.	Jena Beakers	555B at	$.18	$2.16
24–	250 cc.	Jena Beakers	557B at	$.16	$3.84
6–	1000 cc.	Erlemeyer Flasks	768E at	$.21	$1.26
6–	500 cc.	Distillation Flasks	446D at	$.35	$2.10
12–	100 cc.	Volumetric Flasks	504V at	$.25	$3.00
12–	50 cc.	Pipettes	223P at	$.15	$1.80
36–	25 cc.	Pipettes	224P at	$.15	$5.40
				Total	$19.56

As heretofore, if goods are received in good condition, we will send you our check for $19.56 within ten days of date of receipt of shipment.

Very truly yours,
Madison Chemical Works,
By (Sig.) T. L. Lund,
Manager.

(4)

1397 Erin Avenue,
Madison, Wisconsin,
April 30, 1915.

Iowa Brass Company,
Mansfield, Iowa.

Gentlemen:

Please ship us the following items by way of the C. E. and I.:

75 No. 8648 Side Bearing Sheradized Insulators.
150 No. 7554—12″ Uninsulated Sheradized Turnbuckles.
24 No. 1080 Malleable Iron Untreated Mine Hangers for 550 volts.

We must have the Hangers by May 15 and the other items by May 20. We will honor a draft drawn to your order for the amount of the shipment in full on May 12.

Very truly yours,
Madison Electric Company,
By (Sig.) John K. Parsons,
Purchasing Agent.

(5)

1397 Erin Avenue,
Madison, Wisconsin,
May 12, 1915.

Iowa Brass Company,
Mansfield, Iowa.

Gentlemen:

We have received your notice of May 7 of the shipping of order E97403 to us over the C. E. and I., but we have not as yet received the bill of lading from the railroad company.

There has evidently been some delay in this shipment, and we should appreciate your coöperation in tracing these articles.

Very truly yours,
Madison Electric Company,
By (Sig.) John K. Parsons,
Purchasing Agent.

(6)

1397 Erin Avenue,
Madison, Wisconsin,
May 15, 1915.

Iowa Brass Company,
Mansfield, Iowa.

Gentlemen:

The shipment of order E97403 was delivered to us to-day by the C. E. and I. R. R. Company, and in checking over the items we have found that 25 of the No. 7554-12 in. Uninsulated Sheradized Turnbuckles have defective threads on at least one end.

Inasmuch as the boxes which contained the articles were received in good order, it would appear that the trouble is in the manufacture and inspection rather than in any damage incurred in transportation.

If you will check this matter up by your inspection records and inform us as to the cause of the defect and as to the adjustment which you are prepared to make, we shall appreciate it.

Yours very truly,
Madison Electric Company,
By (Sig.) John M. Perry,
Receiving Department.

(7)

Mansfield, Iowa,
May 18, 1915.

Madison Electric Company,
1397 Erin Avenue,
ATTENTION: MR. JOHN M. PERRY.
Madison, Wisconsin.

Gentlemen:

We are very sorry to learn from your letter of May 15 that the Turnbuckles which we shipped you on order No. 97403 were defective.

Upon checking up our records we have found that your order of Turnbuckles was filled from a mixed lot which had not been inspected. This mistake was due to the crowded condition of our stock room, which is being rearranged.

We regret exceedingly that we have caused you this annoyance, and consequently we are shipping you by express to-day 25 No. 7554–12 in. Uninsulated Sheradized Turnbuckles.

Very truly yours,
Iowa Brass Company,
By (Sig.) M. K. Nimms,
Adjustment Department.

Professional Letters

A. *Staff Correspondence.*

(8)

[Letterhead]

Reply to Letter of ....
Referring to Meadville.

Livingston, N. J.
Nov. 5, 1914.

Mr. H. W. Washburne, Cadet Engineer,
BUILDING.

Dear Sir:

I wish you would arrange to inspect overhead lines in the Meadville District with a view to ascertaining the number and height of poles; number of cross arms on each pole; number and size of transformers; number and type of incandescent and arc street lighting fixtures; number of lighting arresters, etc.

In other words, we want to take an inventory of all overhead line construction including ground plates, ground pipe, and lightning arrester wiring.

Yours truly,
(Sig.) F. M. Mason,
Engr. Elec. Dept.

FMM/G

(9)

[Letterhead]

Livingston, N. J.
Dec. 24, 1910.

work order 3345.

Mr. G. H. Banfield, Supt.,
Meadville.

Dear Sir:

In connection with work order 3345 completed Nov. 18, 1910, our inspector reports that the primary tap on Dodge Lane has been taken from the Emsley Heights circuit. This should be cut onto the Kendall circuit. He also reports that the transformer pole is not stepped.

Will you kindly see that this work is done and notify this office when it is completed.

Yours truly,
(Sig.) D. M. Thomas,
Engr. El. Distribution.

DMT/G

(10)

[Letterhead]

Livingston, N. J.
December 1, 1912.

H. T. Insulators.

Mr. Raymond Ulrich, Asst. E. E. D.
Building.

Dear Sir:

500 H. T. insulators received from the Ohio Brass Co. on order 62722 were inspected to-day and disposition made as follows:

Accepted		494
Rejected	(off color)	3
"	(broken)	1
"	(cracked)	1
"	(pin hole too small)	1
Total		500

As there are only three of the total number which can not be used, I would recommend that the entire consignment be accepted.

Yours truly,
(Sig.) T. R. Lane,
Inspector.

TRL/K

(11)

[Letterhead]

Req. 1807 WP
Ext.—St. Mary's Hospital.

Livingston, N. J.
April 13, 1915.

Mr. Edward Wildman,
Chief Electrical Engineer,
BUILDING.

Dear Sir:

The attached requisition calls for changes in the line on private property of St. Mary's Hospital.

As explained to me by Mr. Holmes, the buildings are being rewired, and St. Mary's Hospital has requested the Company to bring an additional service into the school building, which is at present connected by an underground from the hospital. This change will give them better service, which at present is poor on account of their inefficient wiring.

If carried out, the changes will require one pole to be set on private property.

In view of the fact that the hospital has been seriously considering the installation of a private plant, Mr. Holmes is very anxious that, if possible, the suggested change be put through without any cost to the hospital. Ordinarily the charge would be $15.00 for the one pole on private property.

Yours very truly,
(Sig.) E. R. Snyder,
Engr. El. Distribution.

ERS/KLW

B. *Outside Correspondence.*

(12)

[Letterhead]

Pot heads. Livingston, N. J.

R. and G. Elect. Specialty Co., December 5, 1915.

196 West Johnson Street, Chicago, Ill.

Gentlemen:

Please quote us on pot heads as follows:

2—Type "M S" two conductor.
2—Type "M C" two conductor.
Compound for filling pot heads.

Above pot heads for use on duplex No. 0 B and S submarine cable; diameter 1⅝ in. over lead sheath. Armoured with No. 6 B and S steel wire. Working voltage 2300.

Also kindly advise weight of pot heads and earliest possible date shipment can be made after receipt of order.

In using the above type pot heads on submarine cables is it customary to run the cable with the armour on into the pot head, or to cut back the armour so that it does not pass through the lower opening?

Yours very truly,
(Sig.) C. N. Bates.
Eng. Elect. Dept.

CNB/H

(13)

[Letterhead]

ATTENTION MR. TUCKER

QUOTATION New York, November 22, 1912.

Livingston Lighting Company,
Livingston, N. J.

Gentlemen:

Confirming our telephone quotation of yesterday, we can furnish:

10,000 ft. Twisted pair 14 B and S telephone wire, each conductor rubber insulated to 5/32″ diameter, separately braided, one of the conductors to have a raised thread to serve as a tracer, at........................$14.75 M. ft.

Net f.o.b. cars, Livingston, N. J.

Terms: 1% cash ten days, or thirty days net.

It is understood that this price is for estimating purposes only.

We hope to hear from you further in this connection.

Yours very truly,
New York Wire and Cable Co.,
Sales Department,
By (Sig.) O. R. Ames.

ORA-DFT

(14)

[Letterhead]

Livingston, N. J.
November 14, 1914.

Mr. C. B. Stover, Engr. of Surveys,
Danville Elec. Light and Pr. Co.,
Danville, N. J.

Dear Sir:

In compliance with your telephone request of this morning I am sending you some information relative to pipe thawing. All of this information was compiled during the winter of 1912–13 as last winter we had no cases of trouble with frozen pipes. I hope that this information will be of use to you.

If you have any similar information which you think we might be able to use, I should appreciate it if you will let me have some of it.

Yours very truly,
(Sig.) T. K. Simpson,
Supt. Repair Dept.

TKS/NIF
Encl. No. 19266

(15)

[Letterhead]

New York, Nov. 3, 1912.

J. S. Miles, Esq.,
Electrical Department,
Livingston Lighting Company,
Livingston, N. J.

Dear Sir:

In accordance with our conversation of this date this is to inform you that both ends of the 3 conductor paper insulated cable which we are making up on order for you, the outside diameter of which we estimate to be about 1-28/32″, should be protected either by end bells or lead pot heads. It is my understanding that both ends of the cable will be indoors, and if this is the case, you can have pot heads formed by a competent jointer or a first-class plumber using pieces of lead pipe measuring 3 to 4″ in diameter, ⅛″ thick and approximately 12″ long. One end can be rounded into a diameter of about 1—28/32″; the other end can be flared out to 4 or 5″ in diameter, the diameter depending upon the piece of pipe used.

Three single rubber cables should be soldered to the paper conductors in such a way that they will be inside the pot head, well separated from one another when the lead pot head is drawn into place and a joint wiped on the cable. The same can then be filled with hot paraffine, and the loss due to the 16 per cent. shrinking of the paraffine on cooling can be taken care of by a second or third pouring. If one end of the cable is to be used under less favorable conditions than above assumed, we would recommend the use of T. and N. pot heads as the cheapest satisfactory form of pot head we know of. For your information we would say that you may reasonably expect a quart of paraffine, which will measure about 58 cu. in. to weigh a trifle under 2 lbs.

We shall be glad to furnish any additional information you may desire.

Very truly yours,
New York Wire and Cable Co.,
By (Sig.) R. B. Adams,
Engineer.

RBA/DHO

(16)

[Letterhead]

Livingston, N. J.
Dec. 6, 1914.

Dec. 2, 1914.
Meadville Trans. Line.

Mr. S. F. Sanborn, D. P. Supt.
Summit Telephone Co.,
Summit, N. J.

Dear Sir:

The subject of new transmission line at Meadville was taken up in detail with Mr. Murphy, and it was decided that we should obtain and turn over to the Telephone Co., certain rights of way on the East side of Bound Brook Rd., in order that our lines might have the west side. This has been done.

In regard to the line on New Broadway between Prospect Ave. and Ashland St., it was explained that we had been unable to obtain the right of way on the west side of New Broadway in front of the Hammond Estate and would therefore be obliged to rebuild our line on the east side (for about three poles). In order to separate our lines at this point, it will be necessary for the Telephone Co. to transfer its interests from the east to the west side of the street; and in order to facilitate this we are willing to stand the expense of making the change and to transfer to the Telephone Co. our poles Nos. 12, 13, and 14 on the west side of New Broadway and obtain a right of way for one other pole on the north-west corner of Broadway and New Broadway. This is the best arrangement we are able to make at this time.

Yours very truly,
(Sig.) D. B. Abbott,
Engr. Elec. Dept.

DBA/HP

(17)

[Letterhead]

St. Louis, U. S. A.
February 26, 1916.
Dictated
February 25, 1916.

Livingston Lighting Company,
Eighth Ave. and First St.,
Livingston, N. J.

Attention of Mr. H. L. Lincoln,
Engr. Elec. Dist.

Gentlemen:

Some time ago Mr. W. M. Helm, our Eastern District Manager, gave you copies of our Fuse Switch Agreement which will allow you the maximum discount on Williams Fuse Switches furnished in quantities; that is, if you purchase them in smaller quantities, as soon as your purchases amount to 100 Williams Fuse Switches, a rebate will be issued to you making the cost $11.50 per Switch instead of the lower quantity price, and as soon as your purchases reach the 200 mark, an additional rebate will be issued to you to bring the cost to $10.00 each.

When you consider the fact that Williams Fuse Switches combine in one device the advantages of a line disconnecting Switch and a Primary Fuse Block and none of the disadvantages, you can readily see that your saving in the long run will be much greater. One of the most important things to be considered is the maintenance expense of your overhead devices. The only item of expense in a Williams Fuse Switch is re-fusing, and this cost is but 2 cents per fuse. Certainly in the course of a few years Williams Fuse Switches will have paid for themselves alone in the saving of re-fusing.

We hope, Mr. Lincoln, that you will see your way clear to execute this Agreement and hope to be in receipt of orders from you for Williams Fuse Switches, which, we assure you, will have our prompt attention.

Yours very truly,
W. B. WILLIAMS AND BROTHER, INC.
(Sig.) M. L. Parker,
SALES DEPARTMENT.

MLP:MCT
WMH

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